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ELECTRIC MINERS' LAMPS.

FOR many years past the question as to the possibility of preventing explosions in coal and other mines has been duly considered, both by mining engineers and Government inspectors; but hitherto the results obtained with the adoption and use of various kinds of safety lamps have not been very successful, and still the problem remains to be solved. Most of the explosions in mines are due to the exposure to the atmosphere of the flame of miners' lamps, or to the fact that where safety lamps are in use, they are not entirely closed to the air. Of course there is a small percentage of explosions which must be attributed to the opening by miners of their lighted lamps, or to the striking of matches for the purpose of lighting pipes; but these form only an insignificant number, and may almost be left entirely out of consideration. The Mines Act of 1887, which came into operation at the commencement of 1888, has greatly conduced to the prevention of explosions. The number of deaths which took place last year from fire-damp explosions was 50, this being the lowest record ever known. These could, of course, have been greatly reduced had electric miners' lamps been used.

The reports of Her Majesty's Inspectors of Mines for 1888 have been issued, and as compared with the previous year a very satisfactory state of affairs is shown. In reference to the lighting of the mines and the best kind of miners' lamps, the general consensus of opinion of the inspectors is that electricity should be the illuminant. Now there is not the slightest reason why an electric miners' lamp should not be introduced at a price which, although it *might* be slightly higher than that of the bonnetted Clanny, the Marsaut, Davy, or the Mueseler, would still be sufficiently cheap to induce colliery and other mine owners to give it a trial with a view to its ultimate adoption. In this connection it may be interesting if we reproduce one of the inspector's recommendations. Mr. Ralph Moore, of the East Scotland district, states: "I have always looked forward for a better and a safer light, to the invention of an incandescent lamp which could be supplied as cheaply and used as handily as the ordinary naked light. With a lamp of this kind there would be no inducement to use any other light, and the difficulty of getting miners to use safety lamps would cease. With the use of an incandescent lamp, so far as miners' lights are concerned, explosions would cease." Similar expressions of opinion are given by the other inspectors.

Various kinds of miners' electric lamps have for some time been placed on the market, but they have not come into favour, and we believe that we are correct in stating that in the United Kingdom there are but two or three mines where such lamps are employed. Among the reasons which may be advanced as the cause of these lamps not having been taken up may be mentioned the higher price, the increase in weight, and the reserve shown by mine owners, who seem to follow the same policy as that pursued by the railway companies, that is to say, they hesitate for a long period before they adopt anything new. A few months ago an electrician in the north of England brought out a miner's lamp, which is, we believe, lighter in weight than any other such lamp in the market when the candle power and lighting hours are considered. It weighed about 2½ lbs., and gave a 1½ C.P. light for ten hours, but no mine owner has as yet been found to take it up. We have before us at this moment another electric miners' lamp—we are, of course, not speaking of that of Coad, which has not yet come to hand—which weighs 3 lbs. and gives a 1 C.P. light for twelve hours. The current is ·323 ampères at 3·75 volts pressure. The lamp, which is contained in a compact wooden case containing the electrolyte and plates, is 5 inches in height, and the diameter 3⅝ inches. This lamp, too, has not come into favour, and other cases might also be cited.

The foregoing remarks show to a great extent the present disadvantages of the miners' lamps hitherto invented, and the question arises, cannot a lamp be brought out which will remedy such defects? We say

decidedly, yes! The lamps which we have inspected have in many instances been very clumsily made without due regard to the actual condition of affairs ruling in mines, and their weight could, in certain cases, have been reduced by half. Whether it will be better to manufacture a primary battery lamp or a secondary battery to be charged by a dynamo, we will not venture to predict, although in the latter case the dynamo could be used for lighting the mines; but we are strongly of opinion that if electrical engineers who are interested in mining would give due attention to the subject and persevere, they would ere long be able to produce an electric miners' lamp as cheap, nearly as light, and more efficient than those lamps now employed in mining operations, the weight of which, we believe, varies from 1 lb. to 1¾ lbs.

THE *Ironmonger* is again on the war path. It is only a few weeks since we drew attention to the absurdity of that journal's theory regarding ironmongers being dealers in electrical apparatus. Now we have another specimen of the immense electrical knowledge possessed by the editor of that highly instructive paper. In its last issue the *Ironmonger* states that "an electric motor has been invented by D. G. Weens (*sic*), Baltimore, which obtained the rate of two miles per minute on a curved track . . . A five mile circular track will be constructed immediately to demonstrate the practicability of the system for passenger service." Our contemporary evidently imagines that the motor runs along the track like a railway train, possibly with passengers bestriding the motor like a man on horseback. Such statements, made by the non-scientific press, do a great deal of harm to the electrical industries, causing as they do an entire misrepresentation of facts. Scissors and paste, together with an ink slinger, will do very well for ordinary subjects, but when it comes to electrical engineering, we would give to the *Ironmonger* Punch's advice to those about to marry, "Don't!"

THOSE municipalities who are considering the advisability of applying for electric lighting powers are taking a long time before they come to any definite decision. That of Bristol is no exception to the rule, and although Mr. Preece's report was handed in some months ago, a conclusion has only just been arrived at. The Electrical Committee of the Bristol Council has just decided to request the Chief Electrician of the Postal Telegraphs to draw up specifications from which the Corporation will be able to advertise for tenders. This matter will be laid before the Council for consideration at their next meeting. Electrical engineers would do well to bear this in mind, especially as several electric lighting companies have already sent in applications, offering either to do the work for the Corporation, or to carry it out themselves.

THE public electric lighting of Leamington will terminate in December. Such is the decision arrived at by the Watch and Lighting Committee of the Leamington Town Council, who have resolved to let the contract with Messrs. Chamberlain and Hookham, which expires in three months, run its course and then die a natural death as regards street lighting in that town. The Lighting Committee have recommended the substitution of Bray's patent gas lamps in three of the main thoroughfares for the glow lamps at present employed. The failure of glow lamp lighting in Leamington points a moral, namely, that in future those concerned in electric street lighting should take care to have proper standards for the lamps and erected at suitable intervals, and that the lamps should not be of low candle-power.

THE Electrician to the Post Office evidently intends to immortalise himself, and the B.A. Meeting of this year has been chiefly remarkable for the views taken by Mr. Preece on the dangers to be apprehended from electric currents of high tension. He was prepared to sit on a barrel of gunpowder through which a copper lightning conductor passed and when a storm was raging; and now he states that no current of electricity can kill a man with certainty. No doubt he is quite ready to make himself the subject of an experiment to confirm his views. This or the lightning rod experiment, if properly carried out, would prove a brilliant success, and would raise hopes of speedy promotion in the ranks of his talented staff. Almost immediately following his remarks comes the news in the New York *Sun* of September 1st, of the death of Mr. Darwin H. Henry, an expert electrician and Superintendent of Construction for the East River Electric Light Company, who was instantly killed on the previous afternoon in the dynamo room of the company's factory by a 1,000 volt alternating current machine. We will undertake to say that Mr. Preece stands alone on the ground he has chosen to take up, and there is not the slightest doubt but that his professional reputation will be seriously impaired by such an exhibition of eccentricity.

AN accident occurred at the local theatre at Hastings the other night which shows the danger of using gas in close proximity to the scenes and the flies. It appears that a "property" basket belonging to the "Dorothy" Company fell against a gaslight and became ignited Fortunately, however, the fire was discovered in time and prevented from spreading. The use of incandescent lamps entirely obviates such danger, and it must be satisfactory to the play-going public that the principal London theatres are in this respect safe.

IT is agreeable to find such a good understanding between employer and *employés* as was shown recently in Colchester, when Mr. James Paxman, the head of the firm of Davey, Paxman & Co., entertained at dinner two of his foremen who had just completed 21 years' service with the firm, and also presented them with a pecuniary acknowledgment of their efforts. The firm has risen from a somewhat small affair to its present importance, and Mr. Paxman asserts that the success has been due to the thorough reliance which it has had in the workmen.

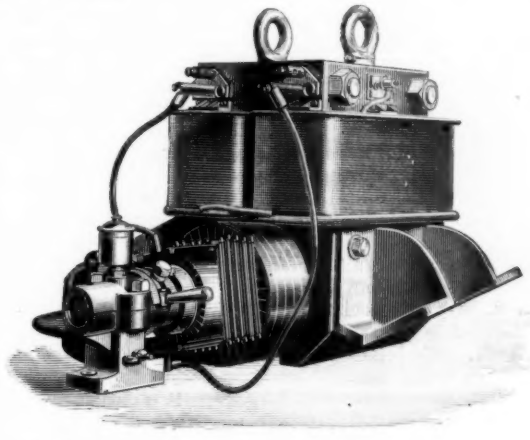
NO definite arrangements will be entered into *re* the Canada-Atlantic cable enterprise until the Dominion Parliament meets during January next; but meanwhile much of the requisite capital has been secured. The north shore land line system will be in operation by the 10th October, and next year connection will be made by duplicate cable routes with Greenly Island, Straits of Belle Isle.

MR. EDISON left 10,000 francs to the poor of Paris as a memento of his visit, and as a testimony of his gratitude for the kindness shown to him and his wife.

MESSRS. W. T. GOOLDEN & CO.'S WORKS.

A RECENT visit to these works has convinced us that the firm came to a very wise determination when they decided to concentrate on this spot their offices which they formerly had at Victoria Street, Westminster, and their works which had been carried on for some years at Halifax. The new establishment is in Woodfield Road, Harrow Road, very near to Westbourne Park Station, a locality conveniently reached from any district of London and from the termini of the great railways. The offices have such a handsome frontage to the street that they might very well be taken for the Paddington Vestry Hall or some equally important public building. On the ground floor are spacious rooms for the managers, book-keepers and clerks, while in the upper storey there are capacious drawing offices and other rooms, all exceptionally well lighted and ventilated. In fact, there are few electrical engineering firms so well off in the matter of offices. The manufactory may be divided into two distinct departments, one being devoted to instrument making and the other to the construction of dynamos and other electrical machinery. The construction of electrical measuring instruments is an important feature of the business, the machinery, tools and testing appliances being all of the most modern and complete kind. The well-known Cardew voltmeters, which are equally useful for direct and for alternating currents are made in several forms, and have recently been much improved. For the measurement of alternating currents these instruments can be made to give at once a direct reading, which remains correct whatever may be the variations in speed of the alternations, the construction of the instrument being such that disturbances either way have the effect of correcting each other. Both in respect of this accuracy and sensibility, and also in the matter of cost, there is an advantage in the use of these instruments in preference to a Siemens dynamometer or Sir Wm. Thomson's instruments. The firm are also sole makers of Evershed's patent gravity ammeters and voltmeters for direct currents constructed for being left constantly in circuit without heating. These instruments possess an advantage over most others in that they take very little current, something like 6 watts as compared with 30 taken by the Cardew and as much as 100 by some others. A new form of Evershed ohmmeter has been recently brought out specially suited for testing insulation resistance of installation work in buildings. This is a practical, handy apparatus, as by its means work of this kind, which would formerly have occupied 10 or 12 hours, can now be completed in two.

Passing to the portion of the premises in which the heavier work is carried on, it is evident that the firm has been determined to be prepared to reap their share of the fruits of that general development of the electrical industry which is already foreshadowed. The works are equipped with machine tools and appliances of the most modern and improved kinds, and ample steam power is available for doing a very large business. Among the small engines which are set apart for special duties is one possessing some historical interest, being the first Armington-Sims that was imported into this country. The lower floor of the main building is devoted to the erecting of machinery, and here are put together not only dynamos but also coal cutting machines, magnetic separators for the treatment of china clay and other special productions of the firm. The improvements effected by Messrs. Goolden & Trotter in the construction of the Gramme machine have been so generally appreciated that they have become incorporated in all good modern dydynamos. On the occasion of our visit we saw ready for delivery a very good form of motor for a launch which, as will be seen from our illustration, is so designed that the whole thing will fit into the bottom of a boat without any further adjustment, the base of the machine being shaped accordingly. This, we understood, had just been completed to the order of a gentleman living on the upper part of the Thames to propel a new launch which is believed to be the best designed boat of this kind on the river. The owner has during the summer proved the feasibility of using a battery of accumulators for the double purpose of boat propulsion by day and house lighting at night, and inasmuch as the demand for house lighting increases as the season for launch driving wanes, the idea seems a very sensible one.



The upper floor of this part of the premises provides ample room for armature winding and for the lighter tools employed in brass finishing, arc lamp work, and other operations of a like kind, such as the putting together of the fire-proof resistance frames of registered designs, to which we referred in our issue of June 28th.

The business hitherto transacted by the firm has been of a high class, and much of the early work in fitting ships of the Royal Navy was intrusted by the Admiralty to Messrs. Goolden & Co. We are convinced that the rearrangement of their business will enable them to do their work in the future, not, perhaps, with any greater satisfaction to their clients, but with more ease to themselves and under better conditions generally.

ENGLISH v. FRENCH DYNAMOS.

IN the ELECTRICAL REVIEW of August 30th, we announced that the Paris Municipal Council had decided upon the purchase of Ferranti (English) machines, and transformers of the same system, the other competitors being MM. Naze and Dandeu. The latter gentlemen, feeling aggrieved, have just issued the following protest, which we print below :—

Monsieur le Président :—We have just read on the door of a *mairie* the *comple-rendu* of the sitting of the Municipal Council of August 10th, and we have seen posted up on the walls the declaration of the Director of Works, couched as follows :—Here is, gentlemen, the situation :—The Commission has issued a tender for a machine of the Ferranti system. Several competitors presented themselves, and here is the note I have received on the subject :—"The sub-commission delegated by the Technical Commission of the Halles Works to examine the high-tension alternating machine presented by MM. Dandeu and Naze, as a competitor with the Ferranti machines, proceeded *yesterday* to its experiments. MM. Potier and Carpentier went to the Weyher and Richemond Works at Pantin, in order to work this new dynamo, which has been judged very imperfect. Constructed for 220,000 watts, it heated as soon as it had produced 60,000 watts, at the end of two hours' working. Under these conditions, hesitation is no longer possible, and I propose to the Council to pronounce on the papers before it." Further on follows the demand made by M. Lyon-Allemand for the purchase of Ferranti transformers. This was all voted and accepted, despite the first remarks of MM. Dumay and Patenne.

We do not hesitate to say that the declarations made in good faith to the Council are, for all that, contrary to the truth, and we address ourselves to you, M. le Président, to protest in the most formal manner against the wording of the famous note sent to the Director of Works. Here are the facts in their scrupulous exactitude :—

We had been officially convoked by the Commission of the Halles Centrales to make experiments on August 6th at MM. Weyher and Richemond, at 9 o'clock in the morning precisely. We declare here that, having waited up till noon, not a single member of the Municipal Council presented himself. There were, therefore, no official experiments with our dynamo. It appears to be necessary to attribute the cause to the Syndic, who forgot to send carriages to the members of the commission. On the 6th we went to MM. Potier, Carpentier, and Hospitalier, apprising them of the situation ; and as MM. Weyher and Richemond had themselves some experiments to make, we informed these gentlemen that we could no longer trespass on their kindness, having awaited five weeks the decision of the Council. On this declaration, MM. Potier and Carpentier decided to come the next day, August 7th, in the afternoon. We forthwith telegraphed to all the members of the commission, informing them that we should be at their service on the 7th, from 9 o'clock in the morning. M. Dumay alone came. We worked from 9 in the morning till 12.15, then from 1.50 till 5.50 in the evening ; or seven hours and not two, as stated in the note sent to M. Alphand. MM. Potier and Carpentier came at 2. On the 8th the measuring apparatus was taken to M. Carpentier to be calibrated. On the 9th, the diagrams of the steam engine were sent to M. Potier. On the 12th, M. Potier caused us to be asked by M. Lafargue for the constant quantities of the exciter. Finally, we may state that, on the 14th, no report had been lodged by the eminent professors who much wished to be present at our experiments. This is, M. le President, the absolute truth. Is it possible to admit that on the 10th such an irregular declaration could have been made ? The machine constructed for 170,000 watts and not for 220,000, could only be worked by an engine of 150 horse-power, kindly placed at our disposal by MM. Weyher and Richemond.

No one is ignorant of the fact, and the Administration less than others, we are pleased to believe, that about 400 horse-power of steam is necessary to produce 220,000 watts. Our experiments proved that the dynamo produced 83,000 watts and not 60,000, that is to say, the maximum the steam engine was capable of. Further on, it is stated that the Ferranti machines, already bought moreover, were made by Cail. Now, according to information, no machine has been made at the Cail factory.

As regards the Ferranti transformers, the matter is still more grave. The only transformer which can legally work in France is that of M. Lucien Gaulard, who died at St. Anne, overcome with bitterness and chagrin, which ended by disturbing his reason. It would really seem that the death of this man of genius was not sufficient to disarm the hatred of his enemies and spoliators. The Municipal Council will doubtless require some light to be thrown on this subject. During a night surprise on December 30th, 1888, the Ferranti tender was passed. The next day, the 31st, MM. Paulard, Dumay, Joffrin, Faillet, Patenne, &c., protested in the name of French interests. On the declaration of M. Alphand, that no dynamo had been purchased, the Council decided that the preference should be given to French trade.

Confiding in this vote and declaration, we did not fear to enter into considerable expense, and our experimental machine, though weak through hurry, is superior in yield to all the other machines of the same nature, and costs much less, 24,000 frs., instead of 33,000 frs. asked by Mr. Ferranti. On August 10th, 1889, it was declared that Ferranti machines had been purchased long since. If that fact be true, what becomes of the vote of the Council, of which we speak above, and its laudable determination to give preference to French industry ? Where are the particulars of the yield of the Ferranti machine to be found ? Who was present at these experiments ? Are experiments simply imposed on Frenchmen ? and are foreigners exempt therefrom ? The surprise of December 30th, 1888, failed ; that of August 10th, 1889, has succeeded.

Thus, in defiance of a deliberation and a vote of the Council, orders were given to a foreigner, and in order to excuse itself it has been declared that our dynamo machine is bad, and that without a regular report from the commission nominated for that purpose, on a simple vote, the author of which it would be interesting to know, as it would be interesting to seek the names of the influential personages who so energetically upheld the interests of the Ferranti firm. A singular way to favour national industries ! In the People's House, from the top of the Municipal tribune, we have been awarded a brevet of incapacity, we, the founders of the first central electrical station in France (Tours, 1885), one ruins us, one pays dearer, but, *en revanche*, one licenses publicly counterfeit to the benefit of foreigners, who take from us at one and the same time our labour and our industrial honour. That is, M. le Président—the result of the sitting of August 10th.

We therefore declare to you, Monsieur le Président, that in the name of French industry, that in the name of our poor and regretted friend, Gaulard, that in the name of right and justice, we are decided to fight to the end. We shall seize the Ferranti apparatus, we shall deliver public lectures, we shall invite all those interested, all French workmen, and shall defy the author of the famous note, which has surprised the good faith of the Director of Works, to dare, in public, to uphold the declaration made to the Municipal Council. Still, before going to such extremities, we address this appeal to the equity of the Municipal Council, to the well known fairness of its president. We will, therefore, still hope that this denial of justice will not be allowed to be carried out ; this denial of justice which may to-morrow, under other forms, attack the whole French industry.

It is in this hope that we have the honour to be, Monsieur le Président, yours, &c.,

DANDEU and NAZE.

This is a very pretty quarrel as it stands, and now the next move is eagerly awaited from the other side.

ELECTRIC LIGHTING AT HOVE.

A SPECIAL meeting of the Hove Commissioners was held last week, to consider the advisability of applying to the Board of Trade for a Provisional Order under, and in accordance with, the Electric Lighting Acts, 1882 and 1888, to authorise the supply of electricity, by the Commissioners, for public and private purposes within the town of Hove. Mr. Woodruff moved that the Town Clerk be instructed to apply for a Provisional Order. He reminded the members that after what was said at the recent inquiry held upon the subject at Brighton, they were virtually pledged to do something in the matter. He thought that the House to House Electricity Company, and the Local Electric Light Company ought not to be allowed to obtain the necessary authority to supply electricity to the people of Hove. He knew that the London promoters of the House to House Electricity Company had organised, he believed, some twenty companies in the Metropolitan district, and ten or eleven subsidiary companies. Those companies had applied to the Board of Trade for electric lighting powers the same as they had asked for at Hove in no less than 224 districts. He contended that such a speculative Company was not likely to give satisfaction in lighting their town. The electric light was rapidly advancing, and was within measureable distance of becoming financially successful, and in applying for a Provisional Order they were only doing what

many towns had done before them. This year a total number of 480 applications for electric lighting powers had been made to the Board of Trade, and out of that number 40 had been applied for by local authorities. He should not say that it would be advisable for the Commissioners to supply the electric light. What they wanted to do was to obtain the Order and hand it over to some safe and reliable Company on terms advantageous to the ratepayers of Hove. The motion was duly seconded, and General Sir C. Shute expressed a hope that if the Order were obtained it would not be made an excuse to delay giving the town the benefit of the electric light. Hove had about the worst and most expensive gas supply in the United Kingdom, and he thought there was no place better adapted for the electric light. The motion was carried.

ELECTRIC LIGHT POSTS AND WIRES AT EXETER.

AT the last meeting of the Exeter Town Council Mr. Yelland asked the Borough Surveyor whether he did not consider that the electric light posts were in many instances erected too close to the buildings. In some cases they were but a few inches from the houses. Mr. Dunn moved that the Town Clerk be requested to make the necessary inquires in order that the Council might be satisfied as to the legality, or otherwise, of the present position of the electric light posts and wires. The motion having been seconded the Town Clerk said the Council must remember that the Exeter Electric Light Company was not a company working under a provisional order. The Surveyor said that the wires were very close to the windows in some instances, but that could not be well avoided. Mr. Alderman Daw asked whether the Surveyor knew that there were regulations passed by the Board of Trade to the effect that electric light wires should not be within six feet of any buildings. The Surveyor said he knew regulations were in force in London to that effect, but he did not know whether they applied to Exeter. The Council granted permission for the erection of posts, and no conditions were laid down. He thought the public in general might rest assured that the best thing in the matter had been done. However, no permission had been given for the construction of the so-called supports to the posts. Instead of supporting the posts they were doing the opposite thing. Communication was made by means of two wires to each house from the main wires and would run over the pathway. Mr. Dunn's motion, after further discussion, was then put and carried. Mr. Dunn gave notice that at the next meeting of the Council, as the Urban Sanitary Authority, he would move that notice be given to the Exeter Electric Light Company to determine the permission given them to erect electric light posts in the public streets at the earliest possible date.

DOMESTIC LIGHTING.

AT the Royal Cornwall Polytechnic Society last week, Prof. Lambert, of the Royal Naval College, Greenwich, in the course of his lecture on "Domestic Lighting" spoke of the necessity of abundant ventilation where gas was burnt. He explained that one ordinary gas burner vitiated the air quite as much as five persons, and a small gas stove as much as 20. He did not consider that water gas would play any part in the future for illuminating purposes, but that it would be largely used in manufactories. With ordinary care petroleum was a good illuminant and twice as cheap as gas.

Electricity was undoubtedly the light of the future, but in small installations he did not think it was likely to supersede gas or petroleum. The expenses attending a 30-lamp installation would be £81, against £38 for gas, but in a large installation, such as one of 2,000 lights, electricity would be cheaper than gas. He firmly believed that before many years had passed electricity would be employed for both lighting and domestic purposes. True it was that millions every year were realised out of the by-products of gas making, and many scientific engineers believed the gas engine to be the engine of the future. Gas would be produced much cheaper and better in years to come, and both that and petroleum would make very good illuminants, yet he still thought they could look forward to the time when their dwellings would be warmed, ventilated and illuminated by electricity.

LONG-DISTANCE TELEPHONY IN NORTHERN EUROPE.

The Telephone Line between Stockholm and Gothenburg.

THE construction of this line, which is 285 miles long, has lately been completed. It consists of four wires —two and two combined—in two separate circuits, and simultaneously available for conversation. The diameter of the wire forming the one circuit is 3 mm., and of the other 2½ mm.; both are made of hard drawn copper wire, with a conductivity of 95 to 98 per cent. of that of pure copper. The wires are suspended on the same poles as the telegraph wires, and they follow the track of the railway. The metallic circuit formed by the wires, which are well insulated and nowhere in connection with the earth, is the means of excluding the sounds produced by currents passing through the earth and also atmospheric disturbances, and as regards the disturbances caused by induction from other wires on the same poles these have been entirely eliminated by continuous twisting of the wires round each other, so that they maintain the same mean average equality of distance between themselves and the disturbing wires. The currents in the latter will induce impulses of equal strength in each branch of the telephone circuits, and these impulses being in opposite directions (for the one wire is used for going and the other for returning) will neutralise each other perfectly, and the result is that no sound is produced in the telephones.

In practice, this arrangement of the wires was effected by placing the four telephone wires so that the supporting points on each pole form a square, and by putting the wires, which belong to one circuit, in the diagonally opposite corners of the square. If the two thick (3 mm.) wires be marked with 1 and 3, and the two smaller (2½ mm.) ones with 2 and 4, the following will represent the relative positions of these wires on five consecutive poles, viz.:—

On the first pole	1—2 4—3
On the second pole	4—1 3—2
On the third pole	3—4 2—1
On the fourth pole	2—3 1—4
On the fifth pole	1—2 4—3, or as on the first pole.

The method adopted on the Stockholm-Gothenburg telephone line is, in short, exactly the same as that which for the last eight years or more has been in use by the General Post Office with so much success, and which was first proposed by Prof. Hughes and afterwards carried out practically by Mr. Moseley near Manchester.

The instruments at work on these telephone circuits are those of the firm L. M. Ericsson & Co., of Stockholm, whose microphone transmitters are well known, and which were described in the ELECTRICAL REVIEW of August 3rd, 1888. P. C. D.

September 14th, 1889.

THE BRITISH ASSOCIATION.

THE DESIGN OF TRANSFORMERS.

Paper read before Section G of the British Association, September 16th, 1889.

By JAS. SWINBURNE.

So much has been already said on the design of transformers, and so many calculations have been made, and so many formulæ given, that it would seem at first sight as if there was little that could be added.

The greatest change that has taken place recently in the practice of transformer design has been the substitution of a continuous iron core interlinked with the copper coils, for a straight core with wires wound on it, as in the Ruhmkorff coil, and the secondary generators of MM. Gaulard and Gibbs. The idea in making this change is that the continuous iron core needs fewer current turns to produce a given induction, and this is generally considered to be of the first importance. With the object of getting the necessary excitation as small as possible, makers give the iron core as large a cross-section and as short a length as possible; and the tendency of designers is to increase the iron and diminish the copper of their transformers. The question of loss of power in heating of the cores does not appear to receive enough attention, and the object of this paper is to point out that many common designs produce very inefficient transformers, and that in many cases a particular form of "open circuit" transformer is the best.

If a transformer, with a full load output of 1,000 watts has a loss of 50 watts in the copper and 150 in the iron, its full load efficiency is 83·5 per cent. But suppose it is put in a house wired for, say, 17 lamps, the full load is on only very occasionally; about half the lamps being the usual maximum. Some authorities take it that the average is equal to all the lamps on one hour a day; others say three or even five hours a day. If the full load is on two hours a day, and the transformer stands idle, merely keeping its iron hot all the rest of the time, its average efficiency is only 35 per cent. Many will at once say that the loss of 150 watts in a 1,000-watt transformer is absurd, and that modern transformers work at something like 98 per cent. full load efficiency. The figures generally given by makers are so obviously impossible, that one is driven to conclude that the loss in iron is not measured.

As a matter of fact, the measurement of this loss is no easy matter. Before bringing forward a paper like this, it might be said that I ought to produce a number of accurate data, giving the loss at various inductions, at various frequencies. Unfortunately, I cannot do so. We must, therefore, rest content with Prof. Ewing's determination of the curve of a single specimen of iron magnetised very slowly. No doubt it is perfectly accurate, but we want a great many curves taken with different samples of commercial iron, and perhaps different frequencies.

It is commonly assumed that a low induction should be used in transformers, because the heat lost per c.c. of iron per cycle is then less; but it is forgotten that more iron is then needed. The volume of iron needed does not vary inversely as the induction, it increases quicker, as the iron is bent round the wire coils. The copper coils have also to surround more iron if its section is increased, and this entails more loss over resistance. On the other hand, the loss per c.c. of iron increases more quickly than the induction, but not much more quickly, so that it may often be advisable to use a high induction.

Before going farther, it will be well to explain some of the terms used in this paper. The square root of the mean square of the electromotive force is called the virtual electromotive force; so that an electrometer or non-inductive voltmeter measures the virtual electromotive force. The square root of the mean square of the current, or the current as measured by a dynamometer, is called the virtual current. Thus the product of the virtual electromotive force and virtual current on a non-inductive resistance give the real power, and so on. Roughly speaking, the virtual current and electromotive force may be taken as 10 per cent. greater than the mean electromotive force. Similarly, the virtual induction is measured by the virtual electromotive force it produces. The mean induction need never be considered, as the question of heating depends on the maximum induction. The virtual induction is thus a maximum of about 10 per cent. less than would be necessary to give the corresponding mean electromotive force. The maximum induction again depends on the maximum excitation, and not on the mean excitation. To get a maximum induction of 1 needs a maximum current of 1; it needs a mean current of about $\frac{2}{\pi}$ or ·64, or a virtual current of about $\frac{1}{\sqrt{2}}$ or about ·7. But a maximum induction of 1 is equal to a virtual induction of about 1·1, so that a virtual induction of 1 needs a virtual exciting current of about ·64. As an example, suppose a long core of one centimetre cross-section wound with wire; and suppose with a direct current one ampère per centimetre produced an induction of 10,000. If the direction of magnetisation alternated perfectly uniformly at a frequency of 2,500 per second, it would induce one volt per turn of wire round it. But if the magnetisation does not increase and decrease perfectly uniformly, the mean electromotive force will remain one volt per turn, but the virtual electromotive force will be greater. Take now the case of an alternating current, and find what virtual exciting current will be needed to induce one virtual volt per turn at a frequency of 2,500. The virtual induction needed will be 9,000. This will need a maximum exciting current of ·9, or a mean current of ·9 × ·64, or a virtual current of ·9 × ·7, or of ·64. If the direct exciting current of 1 lost 1 watt in a given length of wire, the corresponding alternating current will lose only about ·4, or less than half.

In making calculations to find the proportions which give highest efficiency it is clear that the interlinked coils must be as in the figure, in which the single link may be either the

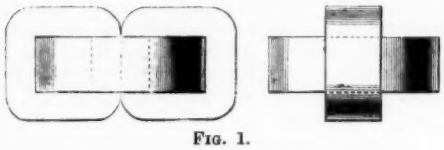


FIG. 1.

copper or the iron. If the cross sectional area of the single link is equal to that of the pair, the pair will have less volume. If the waste of power per cubic centimetre of iron is greater than that of the copper, the wire will take the form of the pair of links, and the single link will be the copper wire. To get the best result the cross-section of the coil and core will be very nearly, but not quite, square. In the following calculations they have been assumed to be square, which can make no perceptible difference in the efficiency, and makes the calculations easier by removing two variables. The problem now proposed is: Given the desired output of the transformer, to design it to give the highest efficiency. Call the side of the section of the iron core x, and the side of the section of the copper core z. All the other dimensions of the transformer depend on x and z. We now have to find the loss in the transformer in terms of known quantities and of x and z, and have then to choose x and z so as to make this loss as small as possible.

The waste in the iron core is equal to the waste per cubic centimetre of iron multiplied by the volume of the iron. Call the loss per cubic centimetre at the induction and frequency under consideration, l. Then

$$\text{Power spent in core} = l\,x^2\,(4\,z + 2\,x) = 4\,l\,x^2 z + 2\,l\,x^3.$$

The loss in a cubic centimetre of copper varies as the square of the current density. The most economical current density ought, properly speaking, to be determined by taking the current density as a variable; but it is generally so high that the coils would get hot. At first sight it may seem strange that a piece of apparatus that gets hot can be more efficient than one that keeps cool; but it must be remembered that the temperature depends on the facility for dissipating the heat, and a large transformer can lose more heat by radiation and convection than a small one, and can thus keep cool, though less efficient. Similarly a dynamo that gets hot is not necessarily inefficient. Heating is inadmissible on the score of durability and safety, so a current density must be assumed that will not cause excessive rise of temperature. The current density can generally be settled beforehand, as the size of the coils will be roughly known, and a safe density can be taken. If the loss per cubic centimetre of copper, with a current density of 1 ampère per square centimetre, is called p, the loss per cubic centimetre of copper is $p\,d^2$, d being the density in ampères per square cm. As the output is known, and the current density is assumed, and the thickness of insulation is also known, the proportion of copper to the whole volume of the coil is known. Call this k.

The loss in the copper is then $k\,z^2\,p\,d^2\,(4\,x + 4\,z)$, so the total loss in the transformer is

$$4\,l\,x^2 z + 2\,l\,x^3 + 4\,k\,p\,d^2\,x\,z^2 + 4\,k\,p\,d^2 z^3.$$

In this expression the extra loss of power due to the magnetising current in the primary coil is neglected, as it is exceedingly small. The magnetising current is itself small, and differs in phase, roughly, a quarter of a period. Thus, if the magnetising current were even 10 per cent. of the full load current, the full load loss in copper would only be about 1 per cent. more than here allowed. If B_v is the virtual induction in the core, and n the vibrations per second, $4\,B_v\,n \times 10^{-8}\,x^2$ is the electromotive force per turn of primary or of secondary wire. The total electromotive force is $4\,B_v\,n\,x^2 \times 10^{-8}$ multiplied by the number of turns in the primary or secondary coil. The output of both coils, or twice the output of the transformer, or $2\,P = 4\,B_v\,n\,x^2 \times 10^{-8}$ multiplied by the ampère turns in both coils. The ampere turns $= k\,d\,x^2$, so that

$$2\,P = B_v\,n \times 10^{-8} \times k\,d\,x^2 z^2$$

therefore

$$z = \frac{1}{x}\sqrt{\frac{2\,P}{4\,B_v\,n\,10^{-8}\,k\,d}}$$

Call the coefficient b, then $z = \frac{b}{x}$

The total loss is thus

$$4\,l\,b\,x + 2\,l\,x^3 + \frac{4\,k\,p\,d^2\,b^2}{x} + \frac{4\,k\,p\,d^2\,b^3}{x^3}$$

TABLE I.—24 hours. 2,000 periods p.m. $l = \cdot 8$.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
2	·0087	·039	·262	2·76	1·325	1·92	14·5	8·75	84	1000	1·25	3
5	·00138	·0617	·4	3·54	1·64	2·15	25·6	19·7	87·5	,,	2·25	6·75
10	·0195	·0875	·5	4·47	1·95	2·3	39·7	28	89	,,	3·45	9·6
25	·0309	·138	·295	9·2	2·5	3·68	100	70	90	,,	8·7	24
35	·0365	·164	·333	10·5	2·75	3·75	124	83·5	90·5	,,	10·6	28
50	·0437	·195	·375	11·5	3	3·84	154	103	92	,,	13·4	35
70	·0517	·231	·41	13	3·22	4·05	188	137	92·8	,,	16·4	47
100	·062	·245†	·49	14·3	3·5	4·07	225	170	94	,,	19·6	59
160	·078	·32†	·54	17·2	3·9	4·43	303	250	94·5	,,	26·3	86
250	·0975	·387†	·6	20·4	4·4	4·62	423	325	95	,,	37	112
400	·1235	·49†	·65	24·8	4·9	4·78	645	420	95·5	,,	56·5	144
650	·157	·624†	·69	30·8	5·5	5·5	700	660	96·5	,,	61	227
1000	·195	·774†	·73	37	6·125	6·07	1095	920	96·75	,,	95	346

TABLE II.—16 hours. 2,000 p.p.m.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
2	·0071	·032	·25	2·31	1·3	1·78	19·7	15·4	77·5	1500	1·14	2·3
5	·0126	·0566	·38	3·3	1·57	2·1	34	35·5	81·25	1200	2·	7·3
10	·0179	·08	·46	3·8	1·77	2·15	46	49	86·4	,,	2·67	14
25	·0309	·138	·295	9·2	2·3	4·03	132	84	87·5	1000	7·7	28·7
35	·0365	·164	·333	10·5	2·55	4·12	168	102	88·5	,,	9·8	35
50	·0437	·195	·375	11·5	2·7	4·27	198	133	90	,,	11·5	45·7
70	·0517	·231	·41	13	2·95	4·4	345	183	90·7	,,	14·2	62·5
100	·062	·245†	·49	14·3	3·05	4·84	285	253	92	,,	16·5	86

TABLE III.—8 hours. 2,000 p.p.m.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
2	·00945	·0425	·317	2·72	1	2·72	21·3	17·8	75·5	850	·62	8·4
5	·015	·067	·424	3·72	1·265	2·84	55	28·5	78·4	,,	1·6	13·5
10	·0212	·0945	·5	4·6	1·48	3·15	82·5	46·3	82·4	,,	2·4	22
25	·0334	·15	·295	10	1·9	5·17	213	108	82·5	,,	6·2	51
35	·0396	·177	·35	11·8	2·2	5·35	300	172	85	,,	8·7	83
50	·0475	·212	·395	12·2	2·3	5·3	330	170	85·7	,,	9·6	80
70	·056	·222†	·47	13·5	2·45	5·5	385	230	87·3	,,	11·2	109
100	·067	·266†	·51	15·2	2·8	5·4	515	245	89	,,	15	116

TABLE IV.—4 hours. 2,000 p.p.m.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
10	·0225	·1	·55	4·9	1·26	3·9	163	68	72·25	750	2·3	41·5
25	·0355	·159	·33	10	1·6	6·25	347	160	75	,,	5	97·5
35	·0425	·189	·36	11·36	1·7	6·65	416	209	78	,,	6	128
50	·0503	·225	·41	12·75	1·9	6·7	532	250	79·5	,,	7·7	153
70	·0595	·264†	·45	14·4	2·05	7	630	313	81·7	,,	9·2	190
100	·071	·318†	·5	16·3	2·22	7·8	720	480	83	,,	10·4	293

TABLE V.—2 hours. 2,000 p.p.m.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
10	·0225	·1	·55	4·9	1·1	4·45	232	95	65	750	1·7	58
25	·0355	·159	·33	10	1·35	7·4	566	250	65	,,	4·1	153
35	·0425	·189	·36	11·36	1·48	7·7	705	305	67·6	,,	5·1	186
50	·0503	·225	·41	12·75	1·61	7·95	870	390	70·5	,,	6·1	239
70	·0595	·264†	·45	14·4	1·8	8	1100	440	73·2	,,	8	269
100	·071	·318†	·5	16·3	1·9	8·6	1310	610	76	,,	9·6	373

TABLE VI.—1 hour. 2,000 p.p.m.

Lamps.	P. w.	S. w.	k.	b.	x.	z.	Power.		Efficiency.	c. d.	Cost.	
							Iron.	Copper.			Iron.	Copper.
10	·0225	·1	·55	4·9	·91	5·4	370	160	53	750	1·35	97·5
25	·0356	·159	·33	10	1·15	8·7	930	385	53·2	,,	3·4	235
35	·0425	·189	·36	11·36	1·25	9·1	1160	500	55·4	,,	4·25	305
50	·0503	·225	·41	12·75	1·375	9·25	1450	587	60	,,	53	360
70	·0595	·264†	·45	14·4	1·49	9·65	1760	750	62·5	,,	6·4	460
100	·071	·318†	·5	16·3	1·62	10	2162	920	66	,,	7·8	560

So that $$4\,l\,b + 6\,l\,x^2 - \frac{4\,k\,p\,d^2\,b^2}{x^2} - \frac{12\,k\,p\,d^2\,b^3}{x^4} = 0$$

or $$3\,l\,x^6 + 2\,l\,b\,x^4 - 2\,k\,p\,d^2\,b^2\,x^2 = 6\,k\,p\,d^2\,b^3$$

This can be solved as a cubic equation for each transformer wanted, or by trial. In practical work an exact solution of such an equation is not required, as any dimensions that even approximately fit the equation give sensibly the same efficiency. Thus x can be made a round number of millimetres, or of eighths of an inch. If a complete table of transformers is wanted it may be shorter to make a finite difference table increasing x^2, the cross-sectional area of the core by jumps of, say, two square centimetres. Or the table may be calculated directly with the aid of a slide rule. In practical work a great deal of time may be wasted, not on legitimate calculations, but on work containing clerical errors, and on trying to find out the mistakes and to see how they got there. Any one who is an inaccurate worker may therefore prefer to make a table in such a way that if the last term is right all the rest must be right too.

A complete set of closed circuit transformers was designed by me for Messrs. Crompton & Co., the waste in copper and in iron, and the cost of material and the efficiencies under various circumstances being worked out. In this case the loss in iron was assumed to be about half as much again as in this paper, as that seemed a fair margin for practical work, though it might not be assumed for argumentative purposes. Most of them were calculated for a frequency of only 33 per second; as I found that led to great saving in the manufacture of the dynamo, and led to small extra cost and loss of efficiency in the transformers, some of these tables may be shortly discussed before going farther. The induction is taken at 14,000, and the loss is taken at 14,600 ergs per c.c. per cycle, or ·024 joules per cubic inch.

The tables were calculated with the object of being useful, so the dimensions are in inches; as in practice one always uses inches. When one's sole object is the advancement of science of course he rises to centimetres.

In Table I., the first column gives the number of 60-watt lamps. The second and third give the diameter or size of wire in inches in the primary and secondary coils. The dagger means that the wire is square. The fourth and fifth give k and b, which are mere coefficients as before. The column x gives the side of the core, and z the side of the coil in inches. The next columns give the loss of power in watts. The cost of material in the last columns is in shillings, taking iron at 3d. and copper at 9d. a pound. Table I. is calculated for transformers on full load the whole 24 hours.

It must be borne in mind that these tables do not give sizes for actual transformers, but act as guides to give the dimensions that should be approached. For instance, the sizes of wires given are no particular wire gauge, and no room is left for cheeks or formers for the coils. The secondary wires would not fall into whole numbers of layers.

Table II. is calculated for 16 hours a day. That is to say, the transformer is supposed to have the secondary open a third of the time. The transformers have then to be re-designed, as the loss in iron becomes relatively more important. It will be noticed that the efficiency begins to fall off and the price to go up. If transformers from Table I. were used only 16 hours a day, the efficiencies would be lower than those in Table II. Tables III. to VI. need no further explanation. It is well to point out that a great deal depends on the way the time is estimated. Full load one hour a day is not the same as half load two hours a day. Half load two hours a day would have less copper waste, so to make the best transformer the copper would be increased and the iron lessened. These last transformers are really absurdities; the 50 lights in Table VI. has an average efficiency of only 60 per cent. and costs about £20 for material only. The E.M.F. has so far been assumed to depend only on the induction in the iron core, but when the core is so small and the coils are so large, this is no longer even approximately true, as will be explained later.

Table VII. is to show what may be gained by transforming from 1,000 to 50 volts instead of from 2,000 to 100. The difference is due to the difference of room taken up by the insulation. The table is made for 50-light transformers, designed for the various times of full load. The column of efficiencies at 2,000 and 100 volts is for transformers designed for these volts, not for the same transformers merely re-wound. The difference would be greater if the same transformer were used in each case. It will be seen that the efficiencies and costs are very little reduced by using low tensions; but as the percentage fall of E.M.F. on the lamps is increased by using the most efficient transformer, it would be best not to design the low-tension transformer with a view to efficiency only.

Table VIII. shows the effect of using transformers for time loads for which they are not intended. It is constructed for various 50-light transformers. The power spent in the copper remains the same in each horizontal line. The waste in the iron during the whole day is concentrated into the hours of lighting, as before. Thus a full time 50-light transformer has an efficiency of 92 per cent. on full time, but only 44·2 per cent. with full load an hour a day. The 50 lighter, specially designed for one hour a day, has an efficiency of 60 per cent., but at 24 hours a day it only rises to 82·3 per cent. The fall of E.M.F. on the lamps is also quite out of the question.

Table IX. shows the percentage fall of secondary E.M.F. at full load. The table, like those before it, is for a frequency of 33. The last two columns show the advantage of using 80 per second. The loss in a 50-lighter is 2·76 instead of 3·42 per cent. in the case of 24 hours, and 14 per cent. instead of 19·5 for the one-hour transformer. The 1,000-lighter would be for sub-stations, and would never have its primary on and its secondary off, so it is taken for 24 hours only. The fall is 1·5 per cent. at 33, and 1·15 at 80.

TABLE IX.—Fall of Sec. E.M.F. 2,000 p.p.m.

Lamps.	Hours. 24	16	8	4	2	1	24 1
2	6·75	12·85	14·85	...	...	...	
5	6·5	11·8	9·5	...	...	...	with 5,000
10	4·65	8·3	7·7	11·3	15·8	26·6	p. per min.
25	4·65	5·6	7·2	10·65	17·75	25·6	
35	3·9	4·95	8·3	10	14·5	23·7	...
50	3·42	4·35	5·65	8·3	13	19·5	2·76 14
50*	3·46	4·25	6·7	8	11·8	17·8	
70	3·25	4·35	5·5	7·5	10·5	17·8	
100	2·83	4·2	4·07	8	10·2	15·3	
160	2·5						
250	2·1						
400	1·8						
650	1·6						
1,000	1·5						1·15

* This line at 1,000 to 50 volts.

It is needless to remark that when the variation of terminal E.M.F. is great, it is very much more important than the efficiency of the transformer itself, as it affects the efficiency of the lamps, and thus of the whole system.

Table X. is for three transformers for a frequency of 80. The 1,000-lighter has an efficiency of 97·2 instead of 96·75, or an increase of ·45 per cent. Its cost of material is £13 10s., instead of £20 10s.

The efficiency of the full time 50-lighter is 93 against 92, and its cost of material is £1 13s. 6d., against £2 8s. 6d. This must, of course, not be confused with the cost of the transformer, which includes many other items.

Leaving these tables, as the induction might be considered too high, and as the loss might also be considered excessive, we may return to our equation:

$$3\,l\,x^6 + 2\,l\,b\,x^4 - 2\,k\,p\,d^2\,b^2\,x^2 = 6\,k\,p\,d^2\,b^3.$$

The more usual frequency of 80 per second will be taken. The current density, d, will be taken at 150 ampères per square cm., which is about 1,000 per square inch. The primary will be taken at 2,000 volts and 1·5 ampères, and the secondary at 100 and 30. Allowing for double cotton insulation, and assuming the sectional area occupied by a wire to be the square of its over-all diameter, k = ·375.

To find l, the waste of power per c.c. of iron for any virtual induction, such as 10,000, we may take the loss per c.c. from Prof. Ewing, and multiply by the frequency; this allows a margin for the air spaces among the wires or plates, and comes about right with round wire. It is not likely that the iron used in commercial transformers is nearly so well annealed as Prof. Ewing's specimen, and it is generally handled a good deal in the workshops. A small allowance should also be made for Foucault currents. Some authorities would also make an addition for viscous hysteresis.

The specific resistance of copper is about 1·8 microhms. All the coefficients in the equation can now be replaced by numbers.

In the tables already given the induction was always 14,000; we will now work out some examples with low and high inductions for various time loads, but always, for ease of comparison, for 50 lamps, or 3,000 watts.

No. 1, with virtual induction of 7,000, designed for full load always on, has an efficiency of 95·2, and a drop of E.M.F of 2·3.

FIG. 2.

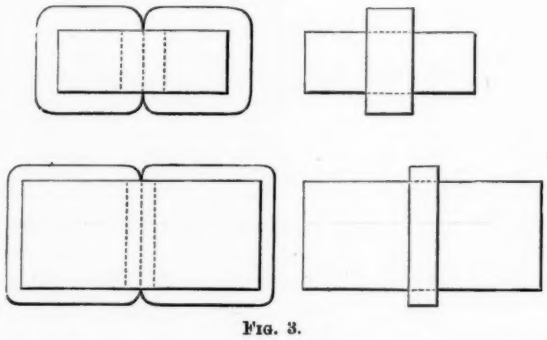


FIG. 3.

The same transformer run at full load for two hours a day, or at half load for 8 hours a day, has an efficiency of 74·7. The figure is to scale.

No. 2, with same induction, designed for two hours a day, has 81·5 efficiency, and at full load always its efficiency goes up to 92. Its drop is no less than 7·3.

No. 3, with virtual induction of 10,600, designed for continuous load, has 95·1 efficiency, and at two hours a day, 72·5; drop 2·2.

TABLE VII.—50 Lamp Transf. 1,000 and 50 volts. 2,000 p.p.m.

P. w.	S. w.	e. d.	Time.	k.	b.	x.	z.	Power.		Efficiency.	Efficiency at 2000 to 100.	Cost.	
								Ieon.	Copper.			Iron.	Copper.
·062	·245†	1000	24	·49	10·1	2·92	3·46	135	104	92·6	9·2	11·7	35·7
,,	,,	,,	16	·49	,,	2·67	3·8	176	128	90·6	90	10·2	44
·067	·266†	850	8	·51	10·75	2·25	4·76	286	202	86	85·7	8·4	100
·071	·28†	750	4	·53	11·2	1·85	6·05	460	240	81	79·5	6·7	146
·071	·318†	,,	2	·53	,,	1·59	7	750	535	73	70·5	5·5	213
,,	,,	,,	1	·53	,,	1·36	8·2	1260	535	62·6	60	4·6	325

TABLE VIII.—50-Light Transformers under various Time Loads. 2,000 p.p.m.

Time.	Power.	24		16		8		4		2		1	
	Copper.	P. Iron.	Efficiency.	P. I.	Efficiency.	P. I.	Efficiency.	P. I.	Efficiency.	P. I.	Efficiency.	P. I.	Efficiency.
24	103	154	92	230	90	460	84·2	920	74·5	1840	60·6	3680	44·2
16	133	133	91·8	198	90·5	396	85	792	76·5	1580	63·7	3168	47·6
8	170	110	91·4	165	89·7	330	85·7	660	78·4	1320	68	2640	51·7
4	250	89	89·9	133	88·6	266	85·4	532	79 5	1064	69	2128	55·6
2	390	72	87·6	108	85·9	217	83·3	435	78·5	870	70·5	1740	58·5
1	587	60	82·3	90·6	81·6	181	79·8	362	76	725	69·6	1450	60

TABLE X.—5,000 p.p.m.

Lamps.	P. w.	S. w.	Hours.	k.	b.	x.	z.	Power.		Efficiency.	Cost.	
								Iron.	Copper.		Iron.	Copper.
1000	·195	·774†	24	·73	23·4	4	5·86	1000	690	97·2	35	237
50	·0437	·195	,,	·375	7·3	1·925	3·8	141	83	93	5	28·5
50	·0503	·225	1	·41	8·1	·875	9·25	1440	420	62	2·6	257

No. 4, same induction, designed for two hours a day, has 81 efficiency, and 91·5 under continuous load, the drop being 8. No. 5, with induction of 14,000, has efficiencies of 94·6 and 71·2, and drop of 2·3.

FIG. 4.

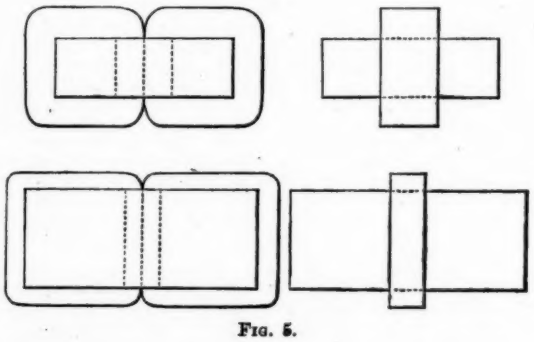


FIG. 5.

No. 5, with induction of 14,000, has efficiencies of 94·6 and 71·2, and drop of 2·3.

No. 6, with same induction, designed for two hours a day, has 77·5, and 90 per cent. on continuous full load. Drop being 9·2.

FIG. 6

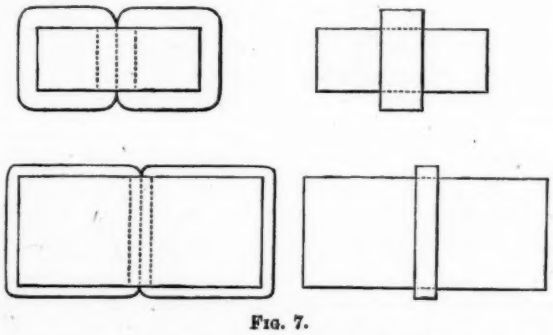
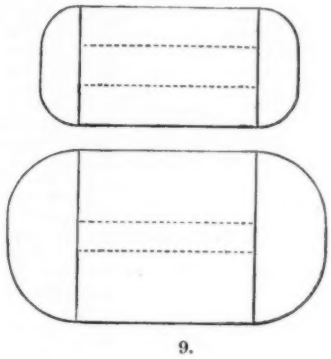


FIG. 7.

These examples show that a low induction is a little better, but it can hardly pay for the extra cost. The chief point is that the best full load transformer is bad for short loads, but a short load transformer, though more efficient at short loads, and not much inferior under continuous full load, is a hopelessly bad regulator, besides being too expensive in copper.

Suppose, instead of a closed iron circuit we use a transformer of the Ruhmkorff coil type. The iron will be less, but the magnetising current will be considerable, especially in small sizes. To reduce this difficulty, I carry the ends of the wire cores out past the cheeks of the coils, and then spread the wires out into a sort of thistle head or hedgehog. The magnetising current cannot even then be left out of account, as it may be very considerable. The magnetising ampère-turns depend on the dimensions of the transformer, and the size and current density of the primary depend partly on the magnetising current, and these quantities are involved in such a way that a calculation to find the best form for a given case gives three complex and unmanageable simultaneous equations. It is much quicker to find the best form by trial, altering one dimension at a time, as independent variable till a good result is obtained.

FIG. 8.



9.

To get the magnetising current, or the primary current at no load, the bushy end is taken as having a hemispherical surface, and the direction of the induction in the air is taken as radial, whereas it really curves round on all sides to the other hemispherical surface. The magnetising current is thus very slightly over estimated. The primary current is taken as the root of the sum of the squares of the magnetising and the main current. Calling the diameter of the core w, the length of the coil and straight part of the core, t, the thickness of winding, z, and the radius of the hemisphere, y, the magnetising ampère turns per cm. of iron, h, the total excitation needed is

$$h\,(t + 2\,y) + \int_y \frac{B_y\, w^2 \cdot 64\, d\, y}{16\, \pi\, y^2}.$$

The first term may be neglected.

As example, No. 7, we may take a medium induction of 10,600, and take w as 5·5, t as 25, and y as 8. At full load, for which this is designed, the efficiency is 96·2; at 2 hours it is 77·3, and the drop is 2·46. In estimating the efficiency at 2 hours a day, allow-

ance is made for the loss in the primary when the secondary is open. This is small in power, but it is of considerable importance, as it is always on.

No. 8 is for short loads. The core is 4 cm. diameter, and the ends 10 cm. radius. Its 2 hours' efficiency is 86·6, and at continuous full load it is 95. The primary current density is here taken less, to keep down the loss due to the no load magnetising current.

TABLE XI.

No.	B_v	Power.		Efficiency.		Drop.
		Iron.	Copper.	24 hours.	2 hours.	
1	7,000	80	65·5	95·2	...	2·3
,,	,,	960	,,	...	74·7	,,
2	,,	453	220	...	81·5	7·3
,,	,,	38	,,	92	...	,,
3	10,600	88	66·5	95·1	...	2·2
,,	,,	105·6	,,	...	72·5	,,
4	,,	477	240	...	81	8
,,	,,	40	,,	91·5	...	,,
5	14,000	101	69	94·6	...	2·3
,,	,,	1212	,,	...	71·2	,,
6	,,	590	275	...	77·5	9·2
,,	,,	49	,,	90	...	,,
7	10,600	44·5	74	96·2	...	2·46
,,	,,	534	349	...	77·3	,,
8	,,	276	197·5	...	86·5	4·35
,,	,,	23	130·5	95	...	,,

Table XI. shows these results for easy comparison. It will be seen that the last example has at full load almost as high an efficiency as 1 or 3, which were specially designed for full loads. At two hours it is very much superior; but its drop is rather serious, and it takes a lot of copper. No. 7, on the other hand, though designed for constant full load, has nearly as high a light load efficiency as the closed circuit light load transformers, and has a small drop, and has least material of any.

The diagrams show that the closed circuit transformers designed for light loads are absurdities that no one would think of making. It must also be remembered in connection with them that the assumption that the only E.M.F. induced in the coils is due to the core induction is obviously absurd.

Where the copper coils are relatively small, it may be assumed that the electromotive force in each depends only on the iron; but in all the cases given allowance must, in practice, be made for lines of induction which do not pass through the iron, produced by each coil. Obviously it would be best to mix the primary and secondary wires together: but there are great practical objections to this, as the wires are then difficult to insulate properly, and the capacity of the transformer as a condenser may be great enough to involve danger to life.

Probably transformers for very short loads could be made very much better than Nos. 2, 4 or 6, without any iron. In 1882–3, seeing in an electrical text-book that an iron core merely concentrated the lines of induction without increasing their number, and knowing no better myself, I argued that as there was loss of power in magnetising the iron, a transformer with the wires mixed would do without iron. I made one with a commutator driven by a motor for direct currents. It lighted part of a Swan carbon, but gave a very small output, and the commutator sparked. I also tried an alternating current; but, as a matter of fact, the transformer was very badly designed. Messrs. Gaulard and Gibbs were really first with mixed wires, which is not a point of no importance, even with cored transformers. I took out a patent in 1884, when the fees were reduced, but it is not even worth the reduced cost. It is merely a matter of theoretical interest that with mixed wires, and a lavish expenditure on copper, an efficient short load transformer might be made. In the transformers we have discussed the coils must be separated, and the primary has to be given fewer turns, and the secondary more, to give the right output.

The loss by Foucault currents has not been taken into account in this paper, as it can be reduced to any desired extent by laminating or using fine wire; but the plates must be very thin to make it really negligeable.

Take a piece of wire 1 cm. long, of radius r. The virtual E.M.F. on any elementary layer is $4 B_v r^2 \pi n$, and the resistance of such a layer is $\frac{2 \pi r R}{d r}$, where R is the specific resistance of warm iron, say 10 microhms. This gives the power $\frac{2 B_v^2 10^{-16} n^2 \pi r^4}{R}$ in the little piece of wire. There are $\frac{1}{4 r^2}$ pieces per c.c., so the watts per c.c. $= \frac{B_v^2 10^{-16} n^2 \pi r^2}{2 R}$. To reduce the Foucault current heating to one-fifth of the hysteresis heating at an induction of 10,000 with 80 periods per second needs wire ·06 cm. in diameter, which is between Nos. 24 and 23 B.W.G.

The Foucault heating in punchings of sheet iron cannot generally be calculated, but is near enough for our purpose if we take circular punchings like dynamo discs of about the same size. For instance, instead of punchings to suit No. 1, we can take washers of 10 and 20 cm., internal and external diameters. The power lost in a disc by Foucault currents is

$$P = \iint \frac{8 B_v^2 10^{-16} n^2 t^2 \pi r \, dt \, dr}{R} \quad \text{or} \quad \frac{8}{3 R} B_v^2 10^{-16} n^2 t^2 \text{ per c.c.}$$

To give a Foucault current loss equal to one-fifth of the hysteresis loss, with an induction of 10,000 and a frequency of 80, needs sheet iron ·0225 cm., or just over No. 35 B.W.G. Of course there are similar losses in iron cored dynamos. For the thicknesses of iron in common use, the tables I. to X. are probably not far wrong.

In conclusion, it would seem that from the point of view of the coal bill at the central station, that the system of putting transformers permanently on in houses is hopelessly bad. But the coal bill is not everything. The cost of electrical energy does not vary as the coal burned. The house transformer system has also the disadvantage of variations of secondary E.M.F.

Assuming the private transformer system to be necessary, the open circuit transformer, of the kind I have now the honour of explaining, is better for such sizes as 50 lights. If larger sizes are needed the hedgehog kind easily distances the closed circuit; for its drawback is its large magnetising current, and the excitation is less in proportion as the transformer is increased. In all cases a large transformer is more efficient than a small one; its percentage loss decreases faster than the dimensions increase, but the dimensions increase very slowly with the output, so that it takes a very large transformer indeed to get an efficiency of 98 per cent., namely, about 50,000 watts.

If the figures for loss in iron here taken are very low, as seems probable, the arguments in favour of this form of open circuit transformer are very much strengthened. The loss in iron also depends on the frequency, so the higher the frequency the better these transformers are in comparison. It is curious to note that this appears to be a step backwards according to most people's ideas, and that it is also a step towards the original practice of the pioneers of transformer work—Messrs. Gaulard and Gibbs.

The discussion on this paper, having been taken with those read respectively by Major-General Webber and Mr. Killingworth Hedges, will be given with the paper by the former gentleman in an early issue.

TELEPHONIC COMMUNICATION BETWEEN LONDON AND PARIS.

By W. H. PREECE, F.R.S.

(*Section G.—Read September 17th*, 1889.)

THE practicability of speaking by telephone between London and Paris has recently been carefully examined, both by the French and the English electricians. The distance between the two places is 275 miles, viz., 74 miles between London and Dover, 21 miles from Dover to Calais, and 180 miles from Calais to Paris. It is very easy to speak over such a distance, if the wires be aerial and of thick copper; but the insertion of underground wires at each end, and of a cable in the middle, place difficulties in the way that have to be surmounted. It is not a question of apparatus, it is solely the distribution of the electrical resistance and capacity of the different portions of the line and the arrangement and material of the wires. Speech is already commercially maintained between Paris and Brussels (190 miles); Paris and Lille (158 miles); Paris and Rouen (80 miles); Paris and Havre (135 miles), Paris, Lyons, and Marseilles; the latter being a distance of nearly 600 miles, but in all cases they are aerial wires, excepting for a short length (about 2 miles) of underground work in Paris.

The author has experimented on the cables between Dover and Calais, between Holyhead and Dublin, and between South Wales and Wexford. The conditions to be fulfilled are very simple. The circuit must be metallic, the material must be copper, and the product of the resistance of the line (R) and its capacity (K) must not exceed a certain figure. It has been determined roughly by experiment that when

K R =	15,000	speech becomes impossible.
=	12,500	,, ,, possible.
=	10,000	,, ,, good.
=	7,500	,, ,, very good.
=	5,000	,, ,, excellent.
=	2,500 or under	,, perfect.

We have thus a species of Beaufoy's scale applied to telephonic communication.

A circuit approaching as nearly as possible one between London —Paris was made on an artificial cable, and it was found to comply with the requirements. An actual circuit was then made from Worcester through 27 miles of the London underground system to Baldock, on the Great Northern Railway, giving similar electrical conditions, and with the same result. It may be considered as absolutely settled that speech is possible between London and Paris.

In the United States speech is maintained between New York and Boston, 350 miles, and in many instances to distances exceeding that between London and Paris, but they have not to surmount the difficulties of underground wires at each end, and of a cable in the middle.

DISCUSSION.

In answer to the President (Mr. Anderson) and Mr. Biggs, Mr. PREECE said that while the wires between Paris and Marseilles were copper, those between London and the coast between Calais

and Paris, were iron, and it was impossible for iron wire to carry a greater distance than 100 miles. There is also in iron wire a great source of disturbance first of induction, and secondly, the permeability of the wire is such, that over that distance it is absolutely impossible to distinguish sounds with accuracy. With the present apparatus, the figures he had given as to the distance which sound would travel would be correct. But he anticipated very great advance in the means of carrying the currents in the form of conductors, and in the form of circuit. They were on the threshold of the subject, and within the next 10 years great strides would be made. He considered that the difficulty would be surmounted sooner or later.

ON THE E.M.F. PRODUCED BY AN ABRUPT VARIATION OF TEMPERATURE AT THE POINT OF CONTACT OF TWO PORTIONS OF THE SAME METAL.

By HENRY STROUD, M.A.

(*Read September 14th, 1889, before Section A.*)

ACCORDING to the law of Magnus (1851) no thermo-electromotive force can exist in a circuit consisting of one metal, homogeneous in structure, provided there is no discontinuity of form nor abrupt variation of temperature.

Le Roux (1867) performed a number of experiments, showing that a thermo-electric current is produced in a single metal whenever there is dissymmetry with respect to the point of heating.

Ritter, in 1801, and others since, have obtained currents by bringing hot and cold wires in contact, and Franz and Gaugain have pointed out that the effect depends on the state as to oxidation of the surfaces of the metal experimented upon. Some experiments were made by Durham (1871) on the momentary current developed when two platinum wires were brought into contact, the wires being at different temperatures, and he found that the momentary current was proportional to the difference of temperature.

No experiments appear to have been made on the E.M.F. produced when two portions of the same metal are in contact, and the one portion is kept at a high temperature and the other kept at a low temperature. The results of such experiments can be predicted from the thermo-electric diagram, and, conversely, a simple and direct method may thus be obtained for the determination of the Thomson effect. It was with the view of developing this method, which was suggested by the thermo-electric diagram, that the experiments described in this paper were undertaken.

From the thermo-electric diagram, which represents very clearly the researches, theoretical and experimental, of Sir W. Thomson and of Prof. Tait, we should expect the E.M.F. produced at the point of contact of hot and cold portions of the same metal to be in one direction for those metals for which the Thomson effect is positive, and to be in the opposite direction for those metals for which the Thomson effect is negative; copper is a good example of the former, and iron of the latter. In the case of lead, for which Le Roux found that the Thomson effect is inappreciable, we should expect no E.M.F. Moreover, the E.M.F. should be greater, under similar circumstances, the greater the magnitude of the Thomson effect.

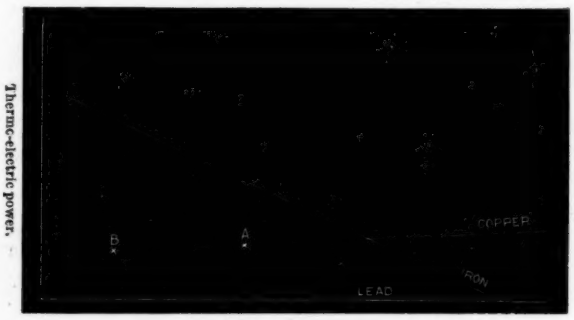


FIG. 1.

In fig. 1 we have represented the iron and copper lines of the thermo-electric diagram, with lead as the metal of reference. If copper, kept at a high temperature, indicated by position "A" in the diagram, is placed in contact with an identical copper conductor, kept at a low temperature, indicated by, say, position "B," we should, it seems to me, expect an E.M.F. to be established from hot to cold, seeing that the Thomson effect in copper is positive; or, in other words, since an electric current flowing through a copper conductor, in which there is a gradual fall of temperature in the direction of the current, has the effect of reducing the differences of temperature, we should expect the contact of hot and cold copper to give rise to an E.M.F. which would be in such a direction as to tend to reduce the difference of temperature, *i.e.*, from hot to cold. Similarly if two identical iron conductors are placed in contact, the one being kept hot and the other cold, we should expect analogous results; but the direction of the E.M.F. would be opposite as the Thomson effect is negative.

The greater the slope of the line representing the metal in the thermo-electric diagram the greater we should expect the E.M.F. to be for a given difference of temperature, for the difference between the thermo-electric powers corresponding to the two temperatures is proportional to the tangent of angle of slope. To find the relation between the E.M.F. and the difference of temperature constitutes part of this investigation; the E.M.F. will be proportional to the difference of temperature in case it is proportional to the difference of the thermo-electric powers corresponding to the two temperatures; for this difference, from the diagram, is represented by

(difference of temperature) × tangent of angle of slope.

Hitherto the experiments made have been chiefly with copper and iron, two typical metals.

From preliminary experiments it was found necessary that the physical condition of the metal experimented upon must be identical throughout the portion of the circuit in which the abrupt difference of temperature was produced, otherwise the thermo-electric E.M.F., due to heterogeneity, quite masked that due to the cause in hand. This condition was satisfied by dividing a tube of the experimental metal, cleaning the surfaces with sand paper, and pressing the similar portions together, a mark on each portion of the tube enabling this to be done very exactly. The surfaces were carefully rubbed down so that good contact was obtained between them when pressed together. The preliminary experiments also showed clearly the necessity of keeping the surfaces in contact free from oxide; the surfaces were therefore cleaned before each experiment.

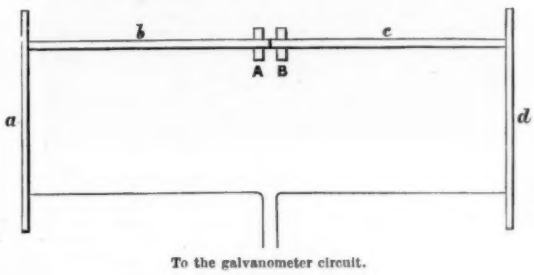


FIG. 2.

In the adjoining figure (fig. 2) is represented the arrangement that has been found suitable. Between the two tubes *a* and *d* were placed the two tubes *b* and *c*, which were pressed together and kept in contact with each other and with the tubes *a* and *d* by means of a spring. *a*, *b*, *c*, *d* were all cut from the same length of tubing, and the ends of *b* and *c* in contact were adjacent portions before cutting. To the ends of the tubes *a* and *d* were soldered the copper or iron wires, which were connected to the galvanometer (a low resistance Thomson), and in the circuit was included a wire which had a resistance of 0·554 ohms. At the ends of this wire was established, by means of a Leclanché cell and an adjustable high resistance, an E.M.F. of such a magnitude as to balance the thermo-electric E.M.F. The contacts of the tubes *a* and *d* with *b* and *c*, and with the soldered wires were kept at the same temperature by means of a constant current of water flowing through the tubes *a* and *d*, which were connected by an India-rubber tube not shown in the figure.

"A" and "B" are two jackets round the adjacent ends of the two tubes *b* and *c*, by means of which the one end can be kept hot and the other cold. A current of steam was used to produce the high temperature and cold water for the low temperature. "A" and "B" were usually about half an inch from the ends of the tubes.

The temperatures of the surfaces in contact were approximately determined by means of two iron German silver junctions, which were placed in small holes drilled as near as possible to the surfaces in contact, the hot junction being bare, while the cold was prevented from touching the metal (and so short-circuiting the E.M.F. to be measured) by means of a small India-rubber tube. It was previously verified that the E.M.F. in this subsidiary temperature circuit was proportional to the difference of temperature of the junctions, and it was found that it = 23 microvolts per degree difference.

Experimenting with ¾-inch copper tubes an E.M.F. was established from hot and cold across the junction, showing that the Thomson effect is positive. The magnitude of the E.M.F. was for one experiment, for which the abrupt difference of temperature at the surface in contact was approximately estimated at 30° C., 6·0 microvolts when "A" was hot and "B" cold, 5·4 microvolts when "A" was cold and "B" hot.

It should be stated that before dividing the tube, of which *b* and *c* formed parts, a similar experiment was made, but no E.M.F. obtained; showing that it is to the discontinuity in the temperature gradient rather than to the steepness of the gradient that the E.M.F. is due.

Similar results have been obtained with ¾-inch iron tubes, no E.M.F. being obtainable when the tube is entire, but on division a E.M.F. from cold to hot across the junction, *i.e.*, in the opposite

direction to that obtained with the copper tubes, and of far greater magnitude. With a difference of temperature approximately estimated at 30° C., the E.M.F. obtained was 74·6 microvolts.

A preliminary experiment has been made, in the case of iron, on the relation between the E.M.F. and the difference of temperature within the range of the above experiments. The method employed was as follows:—When the whole had attained its temperature equilibrium, the steam was stopped while the current of cold water was continued as before; then, while the hot portion

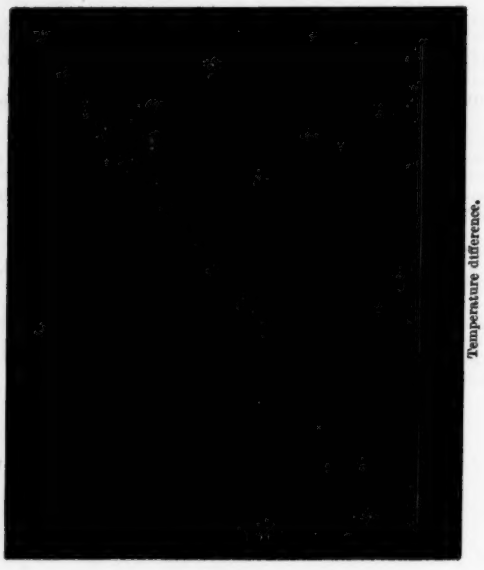


FIG. 3.

was cooling, readings of the two galvanometers were taken alternately, the one galvanometer in the thermo-electric iron German silver circuit indicating the temperature difference, and the other in the main circuit indicating the E.M.F. From these alternate readings, taken at equal intervals of time, simultaneous readings were deduced by interpolation.

On plotting the curve, fig. 3, giving the relation between the E.M.F. and the temperature difference it is found to be a straight line, showing that the E.M.F., in the case of iron and within the range of the experiments, is very nearly proportional to the difference of temperature, as indicated by the junctions placed in the manner described.

The following are the numbers from which fig. 3 was drawn:—

E.M.F.	Temperature Difference.	Ratio.
304·5	382	·797
287	352	·816
272	330	·824
256·5	310	·808
233·5	286	·816
213	267	·798
201	252	·798
188·5	236	·799
176·5	222	·795
165·5	207	·800
155	196	·791
145	182	·797
136	173	·786
128	162	·790
120·5	154	·783
114	144	·792
107·5	137	·785
101	129	·783
95·5	124	·772
90·5	117	·773
85·5	110	·777
81	104	·779
77	99	·778
73	94	·777
69·5	89	·781
66	84	·786
62·5	81	·790
60	77	·779
57·5	74	·777
54·5	71	·768

The results, so far, of these experiments are:—

1. The direction of the E.M.F. is opposite in the case of the two typical metals, iron and copper, being from hot to cold across the junction in the case of copper, and in the reverse direction in the case of iron.

2. The magnitude of the E.M.F. is very much greater for iron than for copper, which corresponds to the much greater slope of the iron line in the thermo-electric diagram.

3. The magnitude of the E.M.F. is, for the case of iron and within the range of the experiments, proportional to the abrupt difference of temperature on either side of the point of contact.

ON THE INSTRUMENTS USED IN THE RECENT MAGNETIC SURVEY OF FRANCE.

By Prof. A. W. RUCKER, F.R.S.

Read September 13th, 1889.

A MAGNETIC survey of France has recently been completed by M. T. Moureaux, who has determined the magnetic elements at some 70 stations. A set of instruments similar to those employed by me has recently been made under the supervision of M. Moureaux for the Science Museum at South Kensington, and these were exhibited.

The point aimed at is their construction, so to secure accuracy combined with dimensions and weight much less than that of the Kew pattern instruments. The weights of the magnetometer and dip circle are only 4 R.G. and 2 K.G. respectively, and the results published by M. Moureaux show high degree of accuracy. The main points in the construction of the instruments were (1), that the needles used are much smaller than those used in the Kew pattern instruments. (2) The end of the declination needle forms a concave mirror, and a reading is taken when the image of linear mark formed by this mirror is in the prolongation to another line which is exactly opposite to the first in a thin piece of metal; (3) the geographical meridian is determined by the theodolite which forms part of the apparatus instead of by using—as the Kew apparatus—a plane mirror to reflect the image of the sun into a horizontal telescope; (4) extremely fine silk thread are able to support a small magnet used (5) in the dip of the circle, the graduated arc rotates in its own plane about a horizontal axis, and a reading is taken when the end of the needle and its image formed by a small concave mirror attached to the graduated circle coincides when viewed through a microscope.

ON HYSTERESIS IN THE RELATION OF STRAIN TO STRESS.

By Prof. J. A. EWING, F.R.S.

(*Read in Section A, September 14th*, 1889.)

It is now well known that when an iron wire is subjected to the alternate application and removal of tensile stress, many times repeated, certain of its qualities which are affected by the changes of stress exhibit hysteresis with regard to the changes of stress. If the load is cyclically varied between definite limits these qualities do not have the same values at corresponding intermediate points during the application and removal of load; there is hysteresis or lagging in the change of quality, and in some cases this appears to be of a static character—that is to say, independent of the time-rate of variation of stress. Conspicuous instances of this action are seen in the change of magnetic and thermo-electric qualities under change of stress, some of which have been described by the author in former papers.

It is natural to look for an effect of the same kind in the extension and retraction which the wire undergoes. We should expect that, after the change of loads has been frequently repeated so that a cyclic *régime* is established, the wire will, for any value of load intermediate between the two extremes, be longer during unloading than during loading. Evidently, if such an effect exist, it must be small, as it is well known that the proportionality of strain to stress which is expressed by Hooke's law is at least approximately exact. Sir W. Thomson's experiments on the damping of terminal vibrators have long ago shown that an action of the kind spoken of occurs in quickly performed cycles of torsional strain. But it does not appear to have been looked for in slow cycles of longitudinal pull.

The author has, with the assistance of one of his students, Mr. D. Low, looked for the effect in question and has found it, not only in iron but in steel, brass, and copper wires. He has not yet examined other metals.

The experiment consisted in observing, with much optical magnification, the extension of a very long piece of wire, directly loaded with lead weights. The wire was hung from a rigid support in a testing flue or recess, built in the wall of the laboratory, and extending up through four storeys. At a distance of 806 cms. below the top a small clamp was fixed on the wire, and this formed the support of the back foot of a little tripod, the feet of which consisted of three needle points about an inch apart. The two front feet rested in a slot and hole in a fixed shelf which stood in front of the long wire. The tripod carried a plane mirror which became tilted forward or backward as the wire extended or retracted. Readings were taken by a telescope of the reflected scale of a levelling staff placed vertically at a distance of some 5 metres from the mirror. The staff was graduated to $\frac{1}{100}$th of a foot, and it was easy to read by estimation to $\frac{1}{1000}$th of a foot, which corresponded to 0·000000102 of the length of the wire. At first a fixed shelf was used to support the two front feet of the mirror, but the effects of temperature were found to be excessive,

although the greatest care was taken to shield the wire from draughts; and the plan was resorted to of hanging the shelf from two adjacent wires of the same material, suspended from the same support as the wire which was to be stretched. In this form the method of optical multiplication was nearly the same as one employed by Mr. Bottomley in recent experiments on the extension of loaded wires by heat.

The first wire tested was of iron, in the hard-drawn state, 0·108 cm. in diameter. A weight of 14 lbs. was kept permanently on it, and an additional weight of 20 kilos. was applied and removed many times. Then readings were taken at intermediate loads (the extreme load caused so much tilting of the mirror that readings could not be taken throughout the whole range), At 10 kilos. (the middle of the cycle) on the way up the scale reading was 2,340; with the same weight on the way down it was 2,305. The difference, due to hysteresis, is 35, or 0·00000357 of the length. The whole extension per kilo. was 533 scale divisions, so that the change of length due to the full load of 20 kilos. was 20 × 533 = 10,660 scale divisions. Hence the amount of difference in length at the middle position or 10 kilos. in the loading and unloading processes was $\frac{35}{10660}$ or say $\frac{1}{300}$th of the whole extension between the extreme load. Another way of stating the result would be to say that the extension had the same value at 10·066 while the load was being increased as it had at 10 kilos., while the load was being diminished: the effect of hysteresis is equivalent to a difference of 66 grammes in the load.

Further experiments were made to test how far this hysteresis depends on the time rate of loading and unloading. In the above case, the cycle of load had been performed as quickly as was practicable, the only pauses being at 10 kilos. on the way up and at 10 kilos. on the way down. It was found that even when the pause at 10 kilos. lasted for two hours no distinct change took place in the readings. So far as this experiment showed, the hysteresis is persistent. It appeared, however, that pauses at the extremes of load has the effect of increasing the difference of readings at the middle. In a slowly performed cycle where a pause of about three minutes was allowed at each step (of two kilos) in the processes of loading and unloading, the difference of the readings at 10 kilos was about 50 scale divisions instead of the 35 divisions observed in the former case.

A similar trial was made with mild steel wire, previously annealed and then hardened by the imposition of a load much greater than the load afterwards used in the testing cycle. Here the wire was 0·94 mm. in diameter. There was, as in a former case, a constant load of 14 lbs., and the cycle was made by applying and removing 12 kilos. At six kilos. the readings were 4,695 and 4,726. Difference 31. The extension per kilo. was 750. Hence the hysteresis is $\frac{31}{12 \times 750} = \frac{1}{290}$ of the extension due to the whole load. With long pauses at the middle load the hysteresis appeared to be reduced to 27 scale divisions, or $\frac{1}{333}$ of the whole extension.

Next, a hard wire of high carbon steel was tested, 0·72 mm. in diameter, by having 14 lbs. permanently on, and loading and unloading 12 kilos. At six kilos. the readings were:—"up" 9,220, creeping to 9,240 in two hours; "down" 9,400, creeping to 9,370 in two hours. Differences 180, and 130.

The extension for 1 kilo. was 1,290, so that the above differences correspond to $\frac{1}{7}$th and $\frac{1}{10}$th of the whole extension respectively. It is remarkable that the hysteresis is decidedly greater here than in the wires previously tested.

A brass wire 1·08 mm. in diameter tested in the same way with 12 kilos. gave readings 6,990 and 7,114 at 6 kilos., difference = 124, which was equivalent to $\frac{1}{107}$th of the whole extension, since the extension for 1 kilo. was 1,100 scale divisions.

With a copper wire 1·15 mm. in diameter, loaded with 10 kilos., the readings at 5 kilos. showed a difference of 52 scale divisions equivalent to $\frac{1}{192}$th of the whole extension.

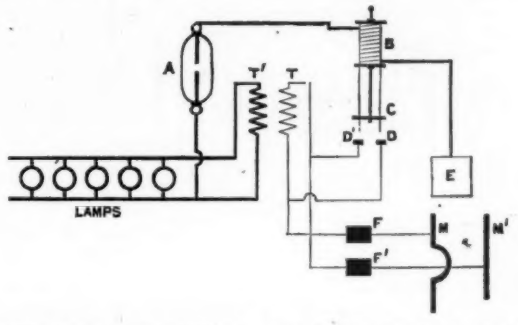
These experiments make it clear that in conditions of loading such as those they deal with, there is a decided departure from Hooke's law, one effect of which is that some work is done upon the material when it is put through a cycle of stress changes. If the relation of strain to stress were represented graphically, the curves would form loops enclosing a certain area. This result has a sufficiently obvious bearing on the conclusions of Wöher with regard to the deteriorating effect of repeated variation of stress.

PRECAUTIONS TO BE ADOPTED WHERE A SUPPLY OF ELECTRICITY IS FURNISHED BY MEANS OF TRANSFORMERS.

By KILLINGWORTH HEDGES, Mem. Inst. Civil Engineers.

(Read on Monday, September 16th, 1889, in Section G.)

IN a paper entitled the "Fire Risks of Electric Lighting," which was read at the meeting of the British Association held in Southport in 1883, I brought forward for the first time the necessity of electric light regulations and the use of safety appliances. The fire insurance companies have almost universally recognised that the electric light can only be considered a safe illuminant, when the strictest attention is paid to the details of an installation; and the regulations which have been published by the principal companies and by the Institution of Electrical Engineers have so far proved successful, as no fire of magnitude can be traced to the electric light. The introduction of transformers has led to the increase of the electromotive force in the primary mains, and there appears to be a tendency to decrease the pressure in the secondary, consequently there is an enormous difference of potential between the two systems and a constant strain on the insulation of the transformer. A transformer may be compared to the reducing valve which converts high pressure steam into the safe pressure for working heating coils. There is, however, this difference—a transformer never sticks like a valve, but it sometimes leaks, and the consequences are similar to those arising from a leaky reducing valve. Supposing a small leak to take place between the primary and secondary coils; it is quite possible that a small current of dangerously high potential might be introduced into the secondary circuit, which would make very little difference to the light from the lamps, but might cause fatal results on any one inadvertently touching some unprotected portion of the wires or fittings with one hand and a gas pipe with the other. To produce this effect it is necessary that some earth should occur on the primary main or mains. With the overhead wires which have almost universally been employed, with alternating currents of high E.M.F., any leakage to earth may be avoided, but with an underground system, and with the increased pressure which is about to be introduced, there is sure to be some earth connection; in fact, with the Ferranti system, one of the conductors is to be earthed throughout. Allowing that a possible danger exists, the question is to find a safe preventive, and with this object it is proposed to briefly recapitulate what has been done. Mr. Kent inserts a metallic shield between the primary and secondary coils of the transformer; this sheet of metal is connected to earth. Now, if the insulation of the primary coil should fail, the leak before reaching the secondary coil must pass through the sheet of metal and thus to earth, causing the primary cut-out to melt and thus cutting out the faulty transformer. The next plan is still simpler, and is to earth the secondary circuit, so that the effect of a contact in the transformer would be to establish connection through the earth and to



A, Vacuum cut-out; B, Electro-magnet; C, Short circuiting device; D, Stops for ditto; E, Earth; F and F$_1$, Fuses; M and M', Mains; T and T', Transformer coils.

FIG. 1.

blow out the primary fuse as in the previous method. It has been stated by several high authorities that this arrangement is all that is wanted to secure perfect safety against shock, but the question of fire risks has also to be considered, and these would be greatly increased, also the insulation of the wires in houses would have to be of the most expensive character. Allowing that every care had been taken with the insulation, the proximity of gas and water pipes in a house to the wires, which are often laid under floors, might open a path for the deviation of a leakage current, say, of 2,000 volts or over, and an arc once formed would result in a dangerous fire. The fire insurance offices have not sanctioned this plan, which does not even appear to be used in those go-ahead institutions, the electric light companies of the United States, who apparently employ no safeguards, and trust to Providence with regard to the "burn out" of a transformer, having a ready supply of duplicate parts to at once replace in the faulty instrument. We now come to the intermittent earth device, that is the automatic apparatus which only comes into play when the potential in the secondary has dangerously increased. Dr. Fleming has described an instrument which consists of a fine wire safety catch holding down suitable contact pieces in mercury cups against the pressure of a spring. The safety catch would be arranged to stand the normal difference of potential between the two secondary mains, but as soon as that rose beyond a certain amount the circuit would be automatically broken. This plan has the disadvantage of a certain amount of loss of current, which would be, however, checked by a resistance; but it avoids the necessity of using an earth. Dr. Bernstein advocates his contact plug, which contains a substance, the resistance of which can be made enormous with the normal current, but the heating effect of an increasing current causes the mixture in the plug to be decomposed, and a metallic circuit established. I am unaware whether this has been tried in a circuit from a transformer or not, but am afraid it would not answer in practice. Major Cardew, whose improved apparatus I have the pleasure of showing you to-day, has, so far, produced the most successful device. It has been called the static mousetrap (see fig. 2), in that it goes off directly an unauthorised volt enters it. The arrangement which you see on the table takes the form of a box; in it there are two brass discs, separated one from the other by an insulating washer of ebonite. Between the two discs is placed a small strip of aluminium foil which lies in ordinary on the lower

disc, which is connected to earth. The other disc is in connection with the secondary coil of the transformer, and should any leakage take place from the primary so as to raise the potential in the secondary, say, by 50 per cent., that part of the aluminium foil which is under a projection on the upper disc will be attracted to it, making an electrical connection and starting an arc which short circuits the secondary and causes the primary fuses of the transformer to be melted. Working quite distinctly from Major Cardew, I have also designed a safety appliance, which may be called a "vacuum cut-out." It is on the lines of those lightning protectors which are often used with telegraph cables, but the electrodes are fixed at each end, and cause the current on its way to earth, after leaping across the points, to energise an electro-magnet which releases a short-circuiting device connected with the primary poles of the transformer (see fig. 1). There is one great advantage in my vacuum cut-out, in that it is not affected by dust or moisture, which might impede the static arrangement. In practice, I propose using old incandescent lamps, with their broken filaments sprung, as they often are, one-sixteenth apart. The perfect vacuum must, however, be destroyed, or only high potential will pass, and the current will preferably short circuit across the terminals, instead of leaping across the broken filament. A lamp of this description would cost very little, and could be fixed in the same manner as the Cardew cut-out, without any relay. Numerous experiments were made to ascertain the distance which an alternating current would leap across points in tubes exhausted to a certain amount. The results differed considerably from the figures given by De la

FIG. 2.

FIG. 3.

Rue in his experiments with continuous currents. In one experiment with glass cylinders having conductors hermetically sealed in opposite ends, and with a pressure of 5m/m., less than that equal to an ordinary vacuum, an alternating current of 1,000 volts invariably passed between the ends of the copper electrodes, which were ·3 inches apart. The arc, fig 3, however, did not remain steadily at the ends, but would first run down one electrode to the point where it was connected to the platinum wire, which came through the glass, with the result of fusing it away. The arc would at the same time extend almost to the glass, although the opposite electrode was left intact. The reason for this phenomenon with an alternating current may be perhaps explained in the discussion. In conclusion, I think that all those who intend using high tension alternating currents, for the supply of electric light and power, should be obliged to fix a safety device on the secondary circuit, near the transformer, with the object of not only protecting their own property, but also to do away with the possibility of an unauthorised current being inadvertently led into a building so as to endanger the lives of the public.

The discussion on this paper, having been taken with those read respectively by Major-General Webber and Mr. J. Swinburne, will be published with the paper by the former gentleman in an early issue.

ADDRESS TO THE MECHANICAL SCIENCE SECTION.

By WILLIAM ANDERSON, M.Inst.C.E.,

President of the Section.

I HAVE had considerable difficulty in selecting a subject which should form the main feature of my address. This meeting being held in Newcastle, it seemed almost imperative that I should dwell upon two industries which may be said to have had their genesis here; that I should direct your attention to the extraordinary development of the system of transmitting power by hydraulic agency, and the use of the same agency for lifting enormous weights or exerting mighty pressures, and that I should not neglect to notice a manufacture of specially national importance—that of heavy artillery, and of ships of war sent forth fully equipped and ready to take their places in our first line of defence.

The desire which I felt of treating of these subjects was heightened by the opportunity which it would have afforded of paying a tribute of respect and admiration to the distinguished citizen of this town who by his genius and perseverance created the Elswick Works, raised the character of British engineering, and rendered his country services so eminent that her Majesty has seen fit to recognise them by bestowing honours higher than any which an engineer has hitherto been able to achieve.

But I felt that the themes mentioned, important as they are, have been frequently treated of by able men, and that I would perhaps render more service to Mechanical Science if I drew your attention to a subject which appears to me to be bearing with daily augmenting force on the practical manipulation of the materials used in construction. I allude to the molecular structure of matter. This branch of science has, up to the present time, been left very much in the hands of the chemist and the physicist, and I dare say that many engineers may think that it is by no means desirable to change the arrangement; but I am persuaded that the progress of engineering, the more exact methods of dealing with the properties of materials, the increased demands on their powers of endurance, render it imperatively necessary that mechanics should interest themselves more deeply in their internal structures and in the true meaning of the laws by which their properties are defined.

Five years ago, at Montreal, in his address to the Mathematical Section, Sir William Thomson took for his subject the ultimate constitution of matter, and discussed, in a most suggestive manner, the very structure of the ultimate atoms or molecules. He passed in review the theories extant on the subject, and pointed out the progress which had been made in recent years by the labours of Clausius, of Clerk Maxwell, of Tait, and of others, among whom his own name, I may add, stands in unrivalled prominence.

I will not presume to enter into the field of scientific thought and speculation traversed by Sir William Thomson, because I am only too conscious that both my mathematical knowledge and my acquaintance with the natural sciences is too limited to entitle the views which I may have formed to any respect; I propose to draw attention only to some general considerations, and to point out to what extent they practically interest the members of this Section.

In a lecture delivered at the Royal Institution last May, Prof. Mendeleeff attempted to show that there existed an analogy between the constitution of the stellar universe and that of matter as we know it on the surface of the earth, and that from the motions of the heavenly bodies down to the minutest interatomic movements in chemical reactions the third law of Newton held good, and that the application of that law afforded a means of explaining those chemical substitutions and isomerisms which are so characteristic, especially of organic chemistry.

Examined from a sufficient distance, the planetary system would appear as a concrete whole, endowed with invisible internal motions, travelling to a distant goal. Taken in detail, each member of the system may be involved in movements connected with its satellites, and again each planet and satellite is instinct with motions which, there is good reason to believe, extend to the ultimate atoms, and may even exist, as Sir W. Thomson has suggested, in the atoms themselves. The total result is complete equilibrium, and, in many cases, a seeming absence of all motion, which is, in reality, the consequence of dynamic equilibrium, and not the repose of immobility or inertness.

The movements of the members of the stellar universe are, many of them, visible to the eye, and their existence needs no demonstration; but the extension of the generalisation just mentioned to substances lying, to all appearances, inert on the earth's surface is not so apparent. In the case of gases, indeed, it is almost self-evident that they are composed of particles so minute as to be invisible, in a condition of great individual freedom. The rapid penetration of odours to great distances, the ready absorption of vapour and of other gases, and the phenomena connected with diffusion, compression, and expansion seem to demonstrate this. One gas will rapidly penetrate another and blend evenly with it, even if the specific gravities be very different. The particles of gases are, as compared with their own diameters, separated widely from each other; there is plenty of room for additional particles; hence any gas which would, by virtue of its molecular motion, soon diffuse itself uniformly through a vacuum would also diffuse itself through one or more other gases, and once so diffused, it will never separate again. A notable example of this is the permanence of the constitution of the atmosphere, which is a mere mixture of gases. The oxygen and the nitrogen, as determined by the examination of samples collected all over the world, maintain sensibly the same relative proportions, and even the carbonic acid, though liable to slight local accumulations, preserves, on the whole, a constant ratio, and yet the densities of these gases differ very greatly.

Liquids, though to a much less degree than gases, are also composed of particles separated to a considerable relative distance from each other, and capable of unlimited motion where no opposing force, such as gravity, interferes; for under such circumstances their energy of motion is not sufficient to overcome the downward attractions of the earth; hence they are constrained to maintain a level surface.

The occlusion of gases without sensible comparative increase of volume shows that the component particles are widely separated. Water, for example, at the freezing-point occludes above one and three-quarter times its own volume of carbonic oxide, and about 480 times its volume of hydrochloric acid, with an increase of volume, in the latter case, of only one-third, and sulphuric acid absorbs as much as 600 times its bulk of methylic ether. The quantity of gas occluded increases directly as the pressure, which seems to indicate that the particles of the occluded gas are as free in their movements among the particles of the liquid as they would be in an otherwise empty containing vessel.

Liquids, therefore, are porous bodies whose constituent particles

have great freedom of motion. It is no wonder, consequently, that two dissimilar liquids, placed in contact with each other, should interpenetrate one another completely, if time enough be allowed; and this time, as might be expected, is considerably greater than that required for the blending of gases, because of the vastly greater mobility of the particles of the latter. The diffusion of liquids takes place not only when they are in actual contact, but even when they are separated by partitions of a porous nature, such as plaster of Paris, unglazed earthenware, vegetable or animal membranes, and colloidal substances, all of which may be perfectly water-tight in the ordinary sense of the term, but yet powerless to prevent the particles of liquids making their way through simultaneously in both directions.

The rate of diffusion increases with the temperature; but an increase of temperature, we know, is synonymous with increased molecular motion of the body, and with increased activity of this kind we would naturally look for more rapid interchanges of the moving atoms. Such phenomena are only conceivable on the supposition that active molecular motion is going on in an apparently still and inert mass.

When we come to solid substances the same phenomena appear. The volumes of solids do not differ greatly from the volumes of the liquids from which they are congealed, and the solid volumes are generally greater. The volume of ice, for example, is one-tenth greater than that of the water from which it separates. Solid cast iron just floats on liquid iron, and most metals behave in the same way; consequently, if the liquids be porous, the solids formed from them must be so also; hence, as might be expected, solids also occlude gases in a remarkable manner. Platinum will take up five and a half times its own volume of hydrogen, palladium nearly 700 times, copper 60 per cent., gold 29 per cent., silver 21 per cent. of hydrogen and 75 per cent. of oxygen, iron from eight to twelve and a half times its volume of a gaseous mixture, chiefly composed of carbonic oxide.

Not only are gases occluded, but they are also transpired under favourable conditions of temperature and pressure, and even liquids can make their way through. Red-hot iron tubes will permit the passage of gases through their substance with great readiness. Mr. Goodman stated, during a recent discussion at the Institution of Civil Engineers, that petroleum passed through a red-hot boiler plate half an inch thick, and it is well known that mercury will penetrate tin and other metals with great rapidity, completely altering their structure, their properties, and even their chemical compositions.

The evidence of the mobility of the atoms or molecules of solid bodies is overwhelming. Substances when reduced to powder may, even at ordinary temperatures, be restored to the homogeneous solid condition by pressure only. Thus, Prof. W. Spring, some 10 years ago, produced from the powdered nitrates of potassium and sodium, under a pressure of 13 tons to the square inch, homogeneous transparent masses of slightly greater specific gravity than the original crystals, but not otherwise to be distinguished by them. More than that, from a mixture of copper filings and sulphur he produced, under a pressure of 34 tons per square inch, perfectly homogeneous cuprous sulphide, Cu_2S, the atoms of the two elements having been brought, by pressure, into so intimate a relation to each other that they were able to arrange themselves into molecules of definite proportion; and, still more remarkable, the carefully dried powders of potash, saltpetre, and acetate of soda were, by pressure, caused to exchange their metallic bases and form nitrate of soda and acetate of potash.

The same movements and changes have taken place, and are still going on, in Nature's laboratory. During the countless ages with which geology deals, and under the enormous pressures of superincumbent masses, stratified sedimentary rocks become crystallised and assume the appearance of rocks of igneous origin, and not only so, but rocks of whatever origin, crushed and ground to pieces by irresistible geological disturbances, reconstruct themselves into new forms by virtue of the still more irresistible and constant action of molecular forces and movements. Those who had the privilege of hearing Prof. A. Geikie's brilliant lecture at the Royal Institution last session will remember the striking series of microscopic slides which he exhibited, and by the aid of which he illustrated the changes of structure to which I have alluded.

At high temperatures the same effects are more easily produced, on account of the greater energy of motion of the atoms or molecules. In the process of the manufacture of steel by cementation, or in case-hardening, the mere contact of iron with solid substances rich in carbon is sufficient to permit the latter to work its way into the heart of the former, while in the formation of malleable cast iron the carbon makes its way out of the castings with equal facility; it is a complete case of diffusion of solid substances through each other, but, on account of the inferior and restricted mobility of the particles at ordinary temperatures, a higher degree of heat and longer time are needed than with liquids or gases.

Again, when, by the agency of heat, molecular motion is raised to a pitch at which incipient fluidity is obtained, the particles of two pieces brought into contact will interpenetrate or diffuse into each other, the two pieces will unite into a homogeneous whole, and we can thus grasp the full meaning of the operation known as "welding." By the ordinary coarse methods but few substances unite in this way, because the nature of the operation prevents, or at any rate hinders, the actual contact of the two substances; but when molecular motion is excited to the proper degree by a current of electricity, the faces to be joined can be brought into actual contact, the presence of foreign substances can be excluded, and many metals not hitherto considered weldable, such as tool steel, copper, and aluminium, are readily welded, as many of us witnessed at the hands of Prof. Ayrton in the highly instructive lecture on electricity delivered last year at our Bath meeting. Again, a mere superficial union of different metals takes place readily under the influence of high temperature and moderate pressure, as we see in the operations of tinning, soldering, and brazing. The surfaces of the metals must be made as clean as possible; the solder, which melts at a lower temperature than the metal to be soldered or brazed, is applied, and at a comparatively moderate temperature and under very slight pressure the particles interpenetrate each other; the two metals unite and form an alloy, by the intervention of which the two surfaces are joined. This effect is very well illustrated by the action which takes place at the surface of contact of two dissimilar liquids. If brine, for example, be placed in the lower part of a glass tube, and ordinary water, coloured in some way, be carefully poured on the top, a sharp plane of demarkation will appear, but in a short time the plane of separation will become blurred, and will ultimately disappear, a local blending of the two waters will take place, and will thus present a case of fluid-welding.

It seems plain, therefore, that apparently inert solid masses are also built up of moving particles in dynamic equilibrium, for without such an assumption it would be hard to explain the phenomena to which I have alluded. But in addition to this evidence we can adduce the effects of other forms of energy, which we recognise under the names of radiant heat, light, and electricity. These we know to be forms of motion which can be communicated and converted from one to the other, from the invisible to the visible. The movement which we term radient heat, acting through the instrumentality of the luminiferous ether which is believed, on the strongest grounds, to pervade all space and all matter, is competent to augment the quantity of movement in the particles of substances, and generally to cause an enlargement of volume; and conversely, when the particles, by contact or radiation, part with their heat, either to surrounding objects or to space, the quantity of motion is reduced, the body contracts, and this contraction goes on down to temperatures far below those at which we have to work in practice, and consequently at all ordinary temperatures there must be abundant room for molecular motion.

Again, energy in the form of light operates changes in the surface of bodies, causing colours to fade, and giving to photography the marvellous power which it possesses, decomposing the carbonic acid of the atmosphere in the chlorophyl of green leaves, and determining chemical combinations, such as chlorine with hydrogen to form hydrochloric acid, or carbonic oxide with chlorine to form chlorocarbonic acid. It is inconceivable that these effects could be produced unless the undulations of light were competent to modify the molecular motions already existing in the solid liquid and gaseous bodies affected.

Electricity exerts a similar influence. Generated by the molecular movements caused by chemical activity, whether directly, as in the primary battery, or indirectly, as in the dynamo, it is competent to increase the molecular movements in bodies so as to produce the effects of heat directly applied; it is capable of setting up motions of such intensity as to produce chemical changes and decompositions, to say nothing of the whole series of phenomena connected with magnetism, with induction, or the action through space and through non-conducting bodies, which, as in the case of radiant heat and light, seems to imply the existence of an interatomic ether. Conversely, changes of molecular equilibrium, brought about by the action of external forces, produce corresponding changes in electrical currents: witness the effects of heat, for example, on conductivity and the wondrous revelations of molecular change obtained by the aid of Prof. Hughes's induction balance. The behaviour of explosives illustrates also, and in a striking manner, the effects of disturbing molecular equilibrium. An explosive is a substance which contains in itself, in a solid or liquid form, all the elements necessary to produce a chemical change by which it is converted into the gaseous state. The application of heat, of pressure, or of impact, causes, as in Prof. Spring's experiments, chemical union to take place, first at the spot where the equilibrium is disturbed by the application of external force, and afterwards, with great rapidity, throughout the mass, the disturbance being propagated either by the air surrounding the particles or by the luminiferous ether, with all the rapidity of light; the chemical reaction is accelerated by the pressure which may arise, for example, if the explosive be confined in the chamber of a gun or in the bore-hole of a blast. High explosives, as they are termed, are comparatively inert to ordinary ignition; but when the molecular equilibrium is suddenly disarranged throughout the mass by the detonation of a percussion fuse, combination takes place instantly throughout, and violent explosion follows. In a similar manner some gases, such as acetylene, cyanogen, and others, can be decomposed by detonation and reduced to their solid constituents. Prof. Thorpe has devised a very beautiful lecture experiment, in which carbon disulphide is caused to fall asunder into carbon and sulphur by the detonation of fulminate of mercury fired by an electric spark. In these cases a reverse action takes place, but illustrates equally well the conversion of one form of energy into others, and the consequent disturbance of molecular equilibrium in the substances affected. It seems to me clear, therefore, that the time has come when the conception of dynamic equilibrium in the ultimate particles of matter in all its forms must take the place of the structural system of inert particles. I cannot conceive how the phenomena which I have enumerated can be explained on the supposition that matter is built up of motionless particles—how, for example, a stack of red and yellow bricks could ever change the order of arrangement without being completely pulled asunder and built up again, in

which case an intermediate state of chaos would exist; but I can easily comprehend how a dense crowd of people may appear as a compact mass, streaming, it may be, in a definite direction, and yet how each member of that mass is endowed with limited motion, by virtue of which he may push his way through without disturbing the general appearance; how the junction of two crowds would form one whole, though, perchance, altered in character; and how even Prof. Spring's experiments may be explained by the supposition that bystanders on the edge of a crowd would be forced, by external pressure, to form part of it and partake of its general movements.

It is a suggestive fact that the product of the atomic weight of certain groups of substances and their specific heats is a constant quantity which, for the greater number of the elements, does not differ much from 6·5. This implies that the quantity of heat necessary to raise the the temperature of the atoms of any one of the groups to any given extent is the same; hence these atoms will be endowed with the same amount of energy at any given temperature, and therefore would be competent to replace each other without disturbing the general dynamic equilibrium.

When it is conceded that molecular motion pervades matter in all its forms, and that the solid passes, often insensibly, into the fluid, or even direct into the gaseous, it follows, almost of necessity, that there must be a borderland, the limits of which are determined by temperature and pressure, in which substances are constantly changing from one state to another. This is observable in fusion, but to a more marked degree in evaporation, where the particles are being incessantly launched into space as gas and return as constantly to the liquid state. Henri St. Claire Deville has investigated similar phenomena in chemical reactions; he has found that at certain temperatures and pressures substances fall asunder and combine much in the way in which evaporation takes place, and has given the name of "dissociation" to this property of matter. Prof. Mendeleeff and others have extended the great French chemist's observations, and have formulated the general law that substances are capable of dissociation at all temperatures, not only in the case of chemical unions, but also in that of solutions.

If steel be looked upon as a solution of carbon and iron, then the hardening of steel is explained by the theory that dissociation has taken place at the temperature at which it is suddenly cooled, the sudden cooling fixing the molecular motion at such an amplitude or phase that it gives a characteristic structure, one of the properties of which is extreme hardness. In tempering, the gradual communication of heat causes dissociation again to take place, the molecular equilibrium is modified by the increased energy imparted to the particles, and when suddenly cooled at any point there remains again a distinct substance, composed of iron and carbon, partly in various degrees of solution and partly free, and again possessing special mechanical qualities. That steel, and probably other alloys, differ in the nature of their composition according to the way in which they are worked, both with respect to heat and mechanical pressure, has been abundantly proved by many eminent metallurgists, and especially by Sir Frederick Abel, in the extended researches which he has recently carried out, on the hardening of steel, for the Institution of Mechanical Engineers, and it would appear as a natural sequence that the properties of steel would be greatly affected by the manner in which its temperature was changed, as we, indeed, find that it is when these changes are produced by baths of melted metals, by oil, or by water at different temperatures. The action which takes place may be illustrated by what would happen supposing that a complicated dance, such as the Lancers, were suddenly stopped in various phases of the figures. The component parts would always remain the same, but the relative distribution of the partners would vary continually, and analysis would show that at one time each gentlemen was associated with a particular lady; at another, that two ladies were attached to a single gentleman, while a number of gentlemen had no partners at all; and yet, again, at another, that the movements which were once rectilinear have become circular. In each case the groups would assume a totally distinct appearance.

In support of these views it may be stated that, as far as I know, no pure element is capable of being hardened or tempered, the reason being that no chemical change can take place when there is only one substance; the effect of heat or pressure, however suddenly applied, produces merely a change of form which does not appear to carry with it any corresponding alteration of mechanical properties.

It may be urged, however, that it is unlikely that alloys or solutions could be affected in a manner so marked merely by small changes at comparatively low temperatures; but I would observe that "great and little" are relative terms, and we have abundant evidence of the immense effects produced by what would be called "little" causes. Sir Frederick Bramwell, in his address last year, drew attention to the importance of the "next to nothing." It is not so very long ago that anyone would have been considered a dreamer for propounding a theory that the presence of the fraction of a per cent. of carbon, phosphorus, or sulphur would totally alter the character of iron; that the addition of one two-thousandth part of aluminium to molten iron would make the pasty mass as fluid as water; that the presence of the smallest impurity in copper would have a disastrous effect on its powers of conducting electricity; and that the addition of one-thousandth part of antimony would convert the "best selected" copper into the worst conceivable. I need hardly allude to the great part played in nature by microscopic organisms, and how much of the beauty of our seas and rivers is derived from substances so minute that nothing but the electric beam of Prof. Tyndall is capable of revealing their presence.

There is one more circumstance connected with my subject to which I must draw your attention, because, though its application to the mechanical properties of substances is very recent, it promises to be of great importance. I allude to the periodic law of Dr. Mendeleeff. According to that law, the elements, arranged in order of their atomic weights, exhibit an evident periodicity of properties, and as Prof. Carnelley has observed, the properties of the compounds of the elements are a periodic function of the atomic weights of their constituent elements. Acting on these views, Prof. Roberts Austen has recently devoted much time and labour to testing their exactness with reference to the mechanical properties of metals. The investigation is surrounded by extraordinary difficulties, because one of the essential features of the enquiry is that the metals operated on should be absolutely pure. For chemical researches, a few grains of a substance are all that is needed, and the requisite purity can be obtained at a moderate cost of time and labour; but when mechanical properties have to be determined considerable masses are needed, and the funds necessary for obtaining these are beyond the reach of most private individuals. I cannot help suggesting that wealthy institutions, such as many of those connected with our profession, could not employ their resources more wisely than in giving the means of following up the researches which Prof. Roberts Austen has inaugurated.

In view of the difficulty of obtaining metals of sufficient purity, he selected gold as his base, because that metal can be more readily brought to a state of purity than any other, and is not liable to oxidation. In a communication to the Royal Society made last year, he shows that the metals alloyed with gold which diminish its tenacity and extensibility have high atomic volumes, while those which increase these properties have either the same atomic volumes as gold or have lower ones. The enquiry has only just been commenced, but it appears to me to promise results which, to the engineer, will prove as important and as fruitful of progress as the great generalisation of Mendeleeff has been to chemists. A law which can not only indicate the existence of unknown elements, but which can also define their properties before they are discovered, if capable of application to metallurgy, must surely yield most valuable results, and will make the compounding of alloys a scientific process instead of the lawless and haphazard operation which it is now.

The practical importance of the views I have enunciated are, I think, sufficiently obvious. Everyone will admit that an external force cannot be applied to a system in motion without affecting that motion; consequently matter, in whatever state, cannot be touched without changes taking place, which will be more or less permanent. The application of heat will cause a change of volume, and, at last, a change of condition; the application of external stresses will also produce a change of volume; and it is natural to infer that there must be some relation between the two, and, accordingly, Prof. Carnelley has drawn attention to the fact that the most tenacious metals have high melting points, though here again there is a great want of exactness, partly on account of the difficulty of measuring high temperatures, and partly by reason of the scarcity of pure materials.

Again, long-continued stresses, or stresses frequently applied, may be expected to produce permanent changes of form, and so we arrive at what is termed the fatigue of substances. Stretched beyond their elastic limits, which limits I do not suppose to exist except when stresses are applied quickly, substances are permanently deformed, and the same effects follow the long application of heat. The constant recurrence of stresses, even those within the elastic limit, causes changes in the arrangement of the particles of substances which slowly alter the properties of the latter, and in this way pieces of machinery, which theoretically were abundantly strong for the work they had to perform, have failed after a more or less extended period of use. The effect is intensified if the stresses are applied suddenly, if they reach nearly to the elastic limit, and if they are imposed in two or more directions at once, for then the molecular disturbance becomes very intense, the internal equilibrium is upset, and a tendency to rupture follows. Such cases occur in artillery, in armour plates, in the parts of machinery subject to impact; and, as might be expected, the destructive effects do not always appear at once, but often after long periods of time.

When considerable masses of metal have to be manipulated by forging or by pressure in a heated condition, the subsequent cooling of the mass imposes restrictions on the free movement of some, if not all, of the particles; internal stresses are developed which slowly assert themselves, and often cause unexpected failures. In the manufacture of dies for coining purposes, of chilled rollers, of shot and shell hardened in an unequal manner, spontaneous fractures take place without any apparent cause, and often after long delay, the reason being that the constrained molecular motion of the inner particles gradually extends the motion of the outer ones until a solution of continuity is caused.

Similar stresses occur in such masses as crank shafts, screw shafts, gun hoops, &c. The late General Kalakoutsky some 17 years ago commenced a systematic investigation into the internal stresses in the tubes and hoops of guns and in armour-piercing shells. The method he pursued was to cut discs or rings about half an inch thick off the hoops and shells, to divide the metal of each disc into from four to six rings, to fix by means of silver plugs, on which very finely marked cross-lines were drawn, from four to eight points on the surface of each ring, and then to measure, with extreme exactness, the changes in diameter pro-

duced in every ring by the successive cutting out of the rings. Knowing by direct tests the mechanical properties of his material, he was able, from the changes in the diameters, to calculate what the tangential stresses in every part of each disc were, and to draw inferences as to their fitness for the work they were intended to perform. The same method of investigation has been pursued by Captain Noble of the Elswick Works, and by Lieutenant Crozier of the United States Artillery, with the practical result that probably much more attention will be paid in future to the principles on which the annealing and hardening of steel is carried on. A gun hoop or tube, to be in the best condition to resist a bursting stress, should have its inner surface in a state of compression, and its outer in a state of tension, and the hoops should be shrunk on to the tubes or on to each other with but very little pressure. General Kalakoutsky proposed, in order to set up beneficial internal stresses, that tubes which were being annealed should be cooled from the inside by a jet of steam, of air, of water, or of oil; and he advocated the practice of testing the effects of each new method of manufacture or of treatment by the careful measurements of slices of the finished material instead of working at random, as is still very much the practice. It is evident, also, that a sample of steel cut out of a gun hoop or crank shaft, and tested, can afford no indication of the available tenacity of the same sample *in situ*. When released from the constraint of its surroundings, the particles must, of necessity, change their condition, for the disturbing forces have been removed; and the probability is that, if the steel be good, the test will prove satisfactory, especially if some time be allowed to elapse between cutting out the sample and testing it, and a false security will be engendered such as has often led to disastrous results.

The influence of time on steel seems to be well established; the highest qualities of tool steel are kept in stock for a considerable period; and it seems certain that bayonets, swords, and guns are liable to changes which may account for some of the unsatisfactory results which have manifested themselves at tests repeated after a considerable interval of time. As all these things have been hardened and tempered, there must necessarily have been considerable constraint put upon the freedom of motion of the particles. This constraint has gradually been overcome, but at the expense of the particular quality of the steel which it was originally intended to secure.

I have now laid before you the views respecting the constitution of matter which I think are gaining ground, which explain many phenomena with which we are familiar, and which will serve as guides in our treatment of metals, and especially of alloys; but I must admit that the subject is still by no means clear, that a great deal more definition is wanted, and that we are still awaiting the advent of the man who shall do for molecular physics what Newton did for astronomy in explaining the structure of the universe.

One of the most remarkable features of the last thirty years is the introduction of petroleum, and the wonderful development to which the trade in it has attained.

Under the generic name of petroleum are embraced a vast variety of combinations of carbon and hydrogen, each of which is distinguished by some special property. At ordinary temperatures and pressures some are gaseous, some are liquid, and some solid, and most are capable of being modified by suitable treatment under various temperatures and pressures. The employment of petroleum in the arts is still extending rapidly. Used originally for illuminating purposes, it is now employed as fuel for heating furnaces and steam boilers; as a working agent in heat engines, valuable medicinal properties have been discovered; and as a lubricant it stands unrivalled.

As an illuminant, even in this country, it is, to a large extent, superseding every other in private houses, and even in public lamps, because it gives a cheaper and more brilliant light than ordinary gas, and leaves the consumer free from the tyranny of great and privileged companies.

As fuel it is especially convenient, cleanly, and economical. Stored in tanks of suitable construction, it is sprayed into the furnace without labour and without creating dust and dirt; and it is especially convenient in locomotive and marine work on account of the rapidity, ease, and cleanliness with which it can be run into the tender or into the oil bunkers of a ship. As a working agent in heat engines it is employed in two ways. First, as a vapour, generated from the liquid petroleum contained in a boiler, very much in the same way as the vapour of water is used in an engine with surface condenser, the fuel for producing the vapour being also petroleum. Very signal success has been obtained by Mr. Yarrow and others in this mode of using mineral oil, especially for marine purposes and for engines of small power; there seems to be no doubt that by using a highly volatile spirit in the boiler a given amount of fuel will produce double the power obtainable by other means, and at the same time the machinery will be lighter and will occupy less space than if steam were the agent used. The other method is to inject a very fine spray of hot oil, associated with the proper quantity of air, into the cylinder of an ordinary gas engine, and ignite it there by means of an electric spark or other suitable means. Attempts to use oil in this way date back many years, but it was not till 1888 that Messrs. Priestman Brothers exhibited at the Nottingham Show of the Royal Agricultural Society an engine which worked successfully with oil, the flashing point of which was higher than 75° Fah., and was therefore within the category of safe oils. The engine exhibited was very like an ordinary Otto gas engine, and worked in exactly the same cycle. A pump at the side of the engine forced air into a small receiver at a few pounds' pressure to the square inch. The compressed air, acting by means of a small injector, carried with it the oil in the form of fine spray, which issued into a jacketed chamber heated by the exhaust, in which the oil was vapourised. The mingled air and oil was thus raised to a temperature of about 300°, and was then drawn, with more air, into the cylinder, where, after being compressed by the return stroke of the piston, it was exploded by an electric spark, and at the end of the cycle the products of combustion were discharged into the air after encircling the spray chamber and parting with most of their heat to the injected oil. The results of careful experiments made by Sir William Thomson and by myself on different occasions were that 1·73 lb. of petroleum were consumed per brake-horse power per hour; but the combustion was by no means perfect, for a sheet of paper held over the exhaust pipe was soon thickly spattered with spots of oil.

At the Windsor Show of the Royal Agricultural Society this year Messrs. Priestman again exhibited improved forms of their engine; the consumption of oil fell to 1·25 lb. per brake-horse power per hour, and a sheet of paper held over the exhaust remained perfectly clean. They also showed a portable engine of very compact construction, and quite adapted to agricultural use; the ordinary water cart, which has, in any case, to attend a portable steam engine, being adapted to supply the water necessary to keep the working cylinder of the engine cool.

It is hardly necessary to state that the use of petroleum for furnace purposes of all kinds is increasing very rapidly, and the demand has naturally reacted on the supply in promoting improved means of transport; and Newcastle, again, has led the van in this matter, for Sir William Armstrong, Mitchell & Co. have sent out a fleet of steamers constructed to carry the oil in bulk with perfect safety, both as regards the stowage of a cargo so eminently shifting, and with respect to risk from fire and from explosion.

The enormous consumption of petroleum and of natural gases frequently raises the question as to the probability of the proximate exhaustion of the supply; and, without doubt, many fear to adopt the use of oil, from a feeling that if such use once becomes general the demand will exceed the production, the price will rise indefinitely, and old methods of illumination and old forms of fuel will have to be reverted to. From this point of view it is most interesting to inquire what are the probabilities of a continuous supply; and such an investigation leads at once to the question, "What is the origin of petroleum?" In the year 1877 Prof. Mendeleeff undertook to answer this question; and as his theory appears to be very little known, and has never been fully set forth in the English language, I trust you will forgive me for laying a matter so interesting before you. Dr. Mendeleeff commences his essay by the statement that most persons assume, without any special reason—excepting, perhaps, its chemical composition—that naphtha, like coal, has a vegetable origin. He combats this hypothesis, and points out, in the first place, that naphtha must have been formed in the depths of the earth. It could not have been produced on the surface, because it would have evaporated; nor over a sea bottom, because it would have floated up and been dissipated by the same means. In the next place, he shows that naphtha must have been formed beneath the very site on which it is found—that it cannot have come from a distance, like so many other geological deposits, and for the reasons given above, namely, that it could not be water-borne, and could not have flowed along the surface, while in the superficial sands in which it is generally found no one has ever discovered the presence of organised matter in sufficiently large masses to have served as a source for the enormous quantity of oil and gas yielded in some districts; and hence it is most probable that it has risen from much greater depths under the influence of its own gaseous pressure, or floated up upon the surface of water, with which it is so frequently associated.

The oil-bearing strata in Europe belong chiefly to the Tertiary or later geological epochs, so that it is conceivable that in these strata, or in those immediately below them, carboniferous deposits may exist and may be the sources of the oil; but in America and in Canada the oil-bearing sands are found in the Devonian and Silurian formations, which are either destitute of organic remains or contain them in insignificant quantities. Yet, if the immense masses of hydrocarbons have been produced by chemical changes in carboniferous beds, equally large masses of solid carboniferous remains must still exist; but of this there is absolutely no evidence, while cases occur in Pennsylvania where oil is obtained from the Devonian rocks underlying compact clay beds, on which rest coal-bearing strata. Had the oil been derived from the coal, it certainly would not have made its way downwards; much less would it have penetrated an impermeable stratum of clay. The conclusion arrived at is that it is impossible to ascribe the formation of naphtha to chemical changes produced by heat and pressure in ancient organised remains.

One of the first indices to the solution of the question lies in the situation of the oil-bearing regions. They always occur in the neighbourhood of and run parallel to mountain ranges—as, for example, in Pennsylvania, along the Alleghanies; in Russia, along the Caucasus. The crests of the ranges, formed originally of horizontal strata which had been forced up by internal pressure, must have been cracked and dislocated, the fissures widening outwards, while similar cracks must have been formed at the bases of the ranges; but the fissures would widen downwards, and would form channels and cavities into which naphtha, formed in the depths to which the fissures descended, would rise and manifest itself, especially in localities where the surface had been sufficiently lowered by denudation or otherwise.

It is in the lowest depths of these fissures that we must seek the

laboratories in which the oil is formed; and, once produced, it must inevitably rise to the surface, whether forced up by its own pent-up gases or vapours, or floated up by associated water. In some instances the oil penetrating or soaking through the surface layers loses its more volatile constituents by evaporation, and, in consequence, deposits of pitch, of carboniferous shales and asphalte take place; in other cases, the oil, impregnating sands at a lower level, is often found under great pressure, and associated with forms of itself in a permanently gaseous state. This oil may be distributed widely according to the nature of the formations or the disturbances to which they have been subjected; but the presence of petroleum is not in any way connected with the geological age of the oil bearing strata; it is simply the result of physical condition and of surface structure.

According to the views of Laplace, the planetary system has been formed from incandescent matter torn from the solar equatorial regions. In the first instance this matter formed a ring analogous to those which we now see surrounding Saturn, and consisted of all kinds of substances at a high temperature, and from this mass a sphere of vapours, of larger diameter than the earth now has, was gradually separated. The various vapours and gases which, diffused through each other, formed at first an atmosphere round an imaginary centre, gradually assumed the form of a liquid globe and exerted pressures incomparably higher than those which we experience now at the base of our present atmosphere. According to Dalton's laws, gases, when diffused through each other, behave as if they were separate; hence the lighter gases would preponderate in the outer regions of the vaporous globe, while the heavier ones would accumulate to a larger extent at the central portion, and at the same time the gases circulating from the centre to the circumference would expand, perform work, would cool in consequence, and at some period would assume the liquid or even the solid state, just as we find the vapour of water diffused through our present atmosphere does now. That which is true of changes of physical condition, Henri St. Claire Deville, in his brilliant theory of dissociation, has shown to be equally true with respect to chemical changes; and the cooling of the vapours forming the earth while in its gaseous condition was necessarily accompanied by chemical combinations, which took place chiefly on the outer surface, where oxides of the metals were formed; and as these are generally less volatile than the metals themselves, they were precipitated on to what there then was of liquid or solid of the earth, in the form of metallic rain or snow, and were again probably decomposed, in part at least, to their vaporous condition. The necessary consequence of this action is that the inner regions of the earth must consist of substances the vapours of which have high specific densities and high molecular weights—that is to say, composed of elements having high atomic weights—and that the heavier elementary substances would collect nearer the centre, while the lighter ones would be found nearer the surface. Our knowledge of the earth's crust extends but to an insignificant distance; yet, as far as we do know it, we find that the arrangement above indicated prevails. Hydrogen, carbon, nitrogen, oxygen, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, potassium, calcium, substances whose atomic weights range from 1 to 40, became condensed, entered into every conceivable combination with each other, and produced substances the specific gravity of which averages about 2½, never exceeds 4, and are found near the immediate surface of the globe.

But the mean specific gravity of the earth as determined by Maskelyne, Cavendish and others certainly exceeds 5, and consequently the inner portion of our globe must be composed of substances heavier than those existing on the surface, and such substances are only to be found among the elements with high atomic weights. The question arises, What elements of this character are we likely to find in the depths of the earth? In the first place, since gases diffuse through each other, a certain proportion of the elements of high atomic weight will also be found on the surface of the earth. Secondly, the elements forming the bulk of the earth must be found in the atmosphere of the sun—if, indeed, the earth once formed part of its atmosphere; and of all the elements, iron, with a specific gravity exceeding 7, and with an atomic weight of 56, corresponds best with these requirements, for it is found in abundance on the surface of the earth; and the spectroscope has revealed the very marked presence of iron in the sun, where it must be partly in the fluid and partly in the gaseous state; and consequently iron in large masses must exist in the earth; so that the mean specific gravity of our planet may well be 5, the value which has been determined by independent means.

It is not easy, however, to define in what condition the mass of iron which must exist in the heart of the earth is likely to be. Iron is capable of forming a vast number of combinations, depending upon the relative proportion of the various elements present. Thus, in the blast furnace, oxygen, carbon, nitrogen, calcium, silicon, and iron are associated, and produce, under the action of heat, besides various gases, a carburet of iron and slag, the latter containing chiefly silicon, calcium, and oxygen—that is to say, substances similar to those which form the bulk of the surface of the earth. But these same elements, if there be an excess of oxygen, will not yield any carburet of iron; and the same result will follow if there be a deficiency of silicon and calcium, because of the large proportion of oxygen which they appropriate. In the same way, during the cooling of the earth, if oxygen, carbon and iron were associated, and if the carbon were in excess of the oxygen, the greater part of the carbon would escape in the gaseous state, while the remaining part would unite with the iron. It is certain that, in the heart of the earth, there must have been a deficiency of oxygen, because of its low specific gravity; and the argument is supported by the fact that free oxygen and its compounds, with the lighter elements, abound on the surface. Further, it must be presumed that much of the iron existing at great depths must be covered over and protected from oxygen by a coating of slag; so that, taking all these considerations into account, it is reasonable to conclude that deep down in the earth there exist large masses of iron in part at least in the metallic state or combined with carbon.

The above views receive considerable confirmation from the composition of meteoric matter, for it also forms a portion of the solar system, and originated, like the earth, from out of the solar atmosphere. Meteorites are most probably fragments of planets, and a large proportion of them include iron in their composition, often as carbides, in the same form as ordinary cast iron—that is to say, a part of the carbon is free and a part is in chemical union with the iron. It has been shown, besides, that all basalts contain iron, and basalts are nothing more than lavas forced by volcanic eruptions from the heart of the earth to its surface. The same causes may have led to the existence of combinations of carbon with other metals.

The process of the formation of petroleum seems to be the following: It is generally admitted that the crust of the earth is very thin in comparison with the diameter of the latter, and that this crust encloses soft or fluid substances, among which the carbides of iron and of other metals find a place. When, in consequence of cooling or some other cause, a fissure takes place through which a mountain range is protruded, the crust of the earth is bent, and at the foot of the hills fissures are formed; or, at any rate, the continuity of the rocky layers is disturbed, and they are rendered more or less porous, so that surface waters are able to make their way deep into the bowels of the earth, and to reach occasionally the heated deposits of metallic carbides, which may exist either in a separated condition or blended with other matter. Under such circumstances it is easy to see what must take place. Iron, or whatever other metal may be present, forms an oxide with the oxygen of the water; hydrogen is either set free or combined with the carbon which was associated with the metal, and becomes a volatile substance—that is, naptha. The water which had penetrated down to the incandescent mass was changed into steam, a portion of which found its way through the porous substances with which the fissures were filled, and carried with it the vapours of the newly formed hydrocarbons, and this mixture of vapours was condensed wholly or in part as soon as it reached the cooler strata. The chemical composition of the hydrocarbons produced will depend upon the conditions of temperature and pressure under which they are formed. It is obvious that these may vary between very wide limits, and hence it is that mineral oils, mineral pitch, ozokerit, and similar products differ so greatly from each other in the relative proportions of hydrogen and carbon. I may mention that artificial petroleum has been frequently prepared by a process analogous to that described above.

Such is the theory of the distinguished philosopher, who has framed it not alone upon his wide chemical knowledge, but also upon the practical experience derived from visiting officially the principal oil producing districts of Europe and America, from discussing the subject with able men deeply interested in the oil industry, and of collecting all the available literature on the subject. It is needless to remark that Dr. Mendeleeff's views are not shared by every competent authority; nevertheless the remarkable permanence of oil wells, the apparently inexhaustible evolution of hydrocarbon gases in certain regions, almost forces one to believe that the hydrocarbon products must be forming as fast as they are consumed, that there is little danger of the demand ever exceeding the supply, and that there is every prospect of oil being found in almost every portion of the surface of the earth, especially in the vicinity of great geological disturbances. Improved methods of boring wells will enable greater depths to be reached; and it should be remembered that, apart from the cost of sinking a deep well, there is no extra expense in working at great depths, because the oil generally rises to the surface or near it. The extraordinary pressures, amounting to 300 lbs. per square inch, which have been measured in some wells seem to me to yield conclusive evidence of the impermeability of the strata from under which the oil has been forced up, and tend to confirm the view that it must have been formed in regions far below any which could have contained organic remains.

The weights and measures in use in this country are a source of considerable trouble and confusion. Besides the imperial measures, which are complicated enough, a great number of local units are in use, so that unwary strangers are not unfrequently deceived, or, at any rate, if they hope to escape from mistakes, have to apply themselves to the study of local customs. In the scientific world, again, the metric system is now almost exclusively used, and the same may be said of engineers and manufacturers who have to do with foreign countries in which French measures are in vogue. The same difficulty surrounds the measurement of the power of motors. The unit of power is, indeed, from the nature of the case, common to the whole world—it is unit of weight multiplied by unit of height—and with us the foot-pound, or 33,000 times the foot-pound, is generally accepted; but the difficulty lies in determining how the measure is to be applied. Thus, in the case of a water motor—should the power be calculated by the energy latent in the falling water, or in the actual work given off by the motor? In heat engines we have to deal with many variables. There is the initial pressure of the working agent, the terminal pressure, the length of stroke, the number of revolutions per minute, the indicated power in the cylinder

the effective power given off, and the adequacy of the means of supplying the working agent. In the early days of steam, when pressures were pretty uniform, and speed bore a certain relation to the stroke, the diameter of a cylinder was a tolerably close index to the power of the engine, and such simple rules as "10 circular inches to the horse-power," which prevailed among agricultural engineers, was tolerably intelligible. But in these days, when pressures, speeds, and rates of expansion vary so greatly, the size of the cylinder, or cylinders, is no longer a guide, and I imagine that most manufacturers have ceased to class their engines by their nominal horse-power. The problem is pretty simple in the case of pumping engines, for there the nominal power may be taken, as it is in Holland, to be the actual work performed upon the water, and perhaps a similar rule might apply to motors driving dynamos, but for most other purposes no simple law is possible. In my own practice I have, for many years, been in the habit of classing engines by the indicated horse-power per one revolution for every probable initial pressure, below the maximum one for which the engines were designed, and for various rates of expansion. To facilitate the calculations I use curves which give the theoretical horse-power, on the supposition that steam expands according to Boyle's law, for 10,000 cubic inches of steam measured at the moment of exhaust, which is, in fact, the volume of the cylinder in single-cylinder engines, and the volume of the last cylinder in compounds. These curves are calculated for initial pressures rising by 25 lbs., and, in non-condensing engines, for the extreme range of expansion possible, and to fourteen expansions in condensing engines. The true indicated horse-power ranges from 80 per cent. to 85 per cent. of the theoretical, as above stated, the precise percentage depending upon the construction of the engine. As large engines are now almost always compound, the size of the cylinders is no guide to the lay mind; hence, in answering inquiries, it is necessary by some means to get at the actual horse-power expected and to settle the initial pressure, for on this point there is still much timidity among steam users, so that the engine builder has to adapt himself in this, and other particulars, to the needs or prejudices of his customer.

In marine engines, again, the difficulty is still greater, because the only measure of the effective power of the engines is the speed of the ship under given conditions of immersion. But the resistance of ships is a complicated matter, not perfectly ascertained yet, so that the speed attained in any new combination of engines and hull is by no means a certainty; hence some recognised measure of the power of a marine engine, depending only on the measurement of the cylinders and boilers, becomes very desirable.

So strongly has the want of a standard horse-power been felt by shipbuilders and marine engine makers that the council of the North-East Coast Institution of Engineers and Shipbuilders appointed a committee to investigate the subject, and to devise, if possible, a set of rules which would be generally acceptable. The committee made its report in the spring of 1888. They took as their basis the Indicated Horse-Power under certain normal conditions, and propose to call this the Normal Indicated Horse-Power (N. I. H. P.). The normal conditions are, briefly, the following:—

1. That the steam, of whatever boiler pressure, is expanded to the same terminal pressure.

2. That the expansion is effected by all engines with the same degree of efficiency.

3. That the piston speeds of engines of different lengths of stroke are proportional to the cube root of their respective strokes, and, further, that the actual loaded trial-trip value of piston speed may be taken as 144 times the cube root of the stroke in inches. $(144 \sqrt[3]{S''})$

4. That in cases in which the engines and boilers bear to each other such proportions as to prevent condition 1 from being fulfilled without thereby violating condition 3, the coal consumption per I.H.P. will not be affected, but will be constant for the same boiler pressure.

5. That the boilers are constructed in accordance with what will be generally recognised as the average practice of the present day in respect of the allowance of steam room in relation to power, the diameter, area, and pitch of tubes, the relation of grate to heating surface, and the area of uptakes and funnel; that average natural chimney draught is used, or, if forced draught be employed, that it does not exceed the natural draught; that the horse-power is proportional to the heating surface (H.) and to the cube root of the pressure $(\sqrt[3]{P.})$; and, further, that the actual loaded trial-trip horse-power may be taken as equal to one-sixteenth of the heating surface multiplied by the cube root of the pressure $\frac{(H \sqrt[3]{P})}{16}$.

6. That the efficiency of the engine mechanism is constant, and that the propeller is such as to secure that the engines will utilise the boiler power referred to in condition 5 in the manner prescribed by conditions 3 and 4.

Subject to these conditions the normal indicated horse-power is found by multiplying the square of the diameter of the low-pressure cylinder in inches by the cube root of the stroke in inches, adding to the product three times the heating surface of the boiler in square feet, multiplying the sum by the cube root of the pressure, and dividing the product by 100.

$$\text{N.I.H.P.} = \frac{(D^2 \sqrt[3]{S} + 3\,H)\sqrt[3]{P}}{100}.$$

It is evident from this formula, and from the conditions, that account is taken of all the variables, and that the boiler is regarded as an integral part of the engine. The report gives several useful formulæ deduced from the above. Whether the expressions given are the most convenient possible for general marine practice or not I am not competent to say, but it seems to me that a step has been taken in the right direction in the attempt which has been made to measure marine engines by some rational standard. The members of the committee were all thoroughly practical as well as scientific men; they determined their constants by reference to a large number of successful cases; and I sincerely hope that the question will be pursued by the marine engine builders on the West Coast, and by the constructors of land engines. As engineer to the Royal Agricultural Society I have frequently had to define the power of engines entered for competition for the society's prizes, and I have experienced the greatest difficulty in laying down rules for the guidance of intending competitors, being fearful, on the one hand, of restricting originality, and, on the other, of admitting engines of greatly varying powers.

I have expressed an opinion that the numerous engineering societies which exist at this day have it in their power to promote the advancement of mechanical science in a notable manner by appointing research committees, or by aiding individual investigations from their abundant means. The North-East Coast Institution of Engineers and Shipbuilders has done good service in their endeavours to establish a practical measure of the power of marine engines, while the Institution of Mechanical Engineers has, for the last ten years, been steadily promoting researches of an eminently practical nature. Their expenditure has reached the handsome sum of £1,700, and their proceedings have been enriched with reports on the "Hardening, Tempering, and Annealing of Steel," on the "Form of Riveted Joints," on "Friction at High Velocities," on "Marine Engine Trials," and on the "Value of the Steam Jacket." The names of those who are acting on these committees are a guarantee that the investigations conducted by them will rank among the classical works of the profession, and will abundantly justify the liberal expenditure which has been incurred.

It is impossible to conclude the address which I have had the honour of delivering without an allusion to the most important structure which engineering skill and enterprise has ever attempted. The Forth Bridge is rapidly approaching completion, and on Saturday, September 14th, Mr. Baker is to deliver a lecture, in which he will, no doubt, tell us when the great work is likely to be completed. I think that the members of this Section belong sufficiently to the "working classes" to have a claim to admission to the lecture, and to hear from the lips of the creator of the bridge the story of its inception, of its progress, and his hopes as to its completion.

ELECTRIC LIGHTING AT FAREHAM.

A PUBLIC meeting was held at Fareham on Monday evening to consider the advisability of starting an electric light company in that town.

The chair was occupied by Captain RAMSAY, R.E., a member of the Fareham Local Board, who, in opening the meeting, spoke of the great dissatisfaction rife amongst the ratepayers on account of the high price and bad quality of the gas supplied by the company. He thought 4s. 2d. per thousand feet too dear when the company had water carriage right up to their wharves. It was a great pity that the company had a monopoly and could not be disturbed, and he was sorry that they could not see their way clear to supply their customers with a cheaper and more effective light. There were but two alternatives left to the inhabitants. One was to light the town by oil, the other was to illuminate it with the electric light. As oil was hot, smelt disagreeably, and was not entirely free from danger, they had only left the electric light. As this was not so easy to instal in private houses it was necessary to form a company and to secure co-operation.

Mr. JAMES BLAKE urged the ratepayers of Fareham to no longer submit to the exorbitant demands of the gas company. He did not see why they should pay a heavy price for a bad and impure article in order to benefit the company's shareholders. When the directors had been asked to supply a cheaper and better light the answer invariably was, "how can we do it and pay our shareholders 8 per cent. dividend?" As the popular demand was not acceded to it was for them to consider the advisability of supplying Fareham with the electric light. With this object in view it was proposed to start a "Fareham Electric Light Company, Limited," with a capital of £5,000, divided into 5,000 shares at

£1 per share. He knew of two or three prominent gentlemen who had consented to become directors as soon as the company should be formed. It was estimated that the plant, including steam-power, dynamos, lamps, &c., would cost about £4,000. This would light the town and supply about sixty or seventy private houses and shops. The working expenses would be about £700 per annum, and the receipts about £1,000. They would of course have to have the public lighting guaranteed them before the company was started, but he did not think that there would be much difficulty with the Local Board about that from the feeling expressed that evening, and at the first meeting.

Mr. EDMUND ABRAHAM thought that another attempt should be made to get the gas company to modify their prices and improve the gas. He thought that a reduction to 3s. 6d. per thousand feet would be fair. He did not like to turn upon the company, but unless their just demands were promptly responded to, he, for one, should support the introduction of the electric light into Fareham, and take shares in the new company.

Mr. BLAKE said that no good would be derived by further parleying with the gas company, for they had given the deliberate answer that they could not cut down the price.

Mr. WHITLOCK asked what would be the annual cost of an incandescent lamp?

Mr. BLAKE said it would cost about 15s., and could be very easily fixed in private houses. In the course of some further discussion, Mr. Blake thought that he would be able to dispose of a thousand shares.

Applications for shares, returnable to Mr. Blake, were then distributed among the audience, and should a sufficient number of shares be guaranteed, the company will be formed.

TELEPHONE BETWEEN VIENNA AND PRAGUE.

ON the 10th of this month the new telephonic line from Vienna to Prague was opened. As announced from each terminus, it is in every respect completely successful. The experiments in direct telephonic communication between Vienna and Prague were first made at the Vienna Stock Exchange, and have proved quite satisfactory. Equally successful were the trials of direct communication between the Vienna exchange and the subscribers of the Prague telephone net. A person speaking in Prague, without any exertion of the voice, can be heard distinctly in Vienna to the last syllable, clearly and distinctly. The lead used for this telephonic intercourse does not run along a railway, but passes southwards from Prague *viâ* Sobieslau, Neuhaus, and Newbistritz, to the Bohemian boundary, and in Lower Austria, along the so-called Horner Imperial Road to Vienna. It has been found practicable not only to overcome the effects of induction which so greatly interfere with telephonic intercourse, but to make the line independent of all disturbing atmospheric influences, so that it will always be possible to speak and hear distinctly on the Vienna-Prague line.

Electrical Engineering Classes at Glasgow.—We have received a copy of Professor Jamieson's syllabus of engineering classes for next session, which commences on October 1st and ends on April 30th. There is a preliminary workshop class, and then a complete two years' course of day-class lectures and laboratory work, in addition to the usual evening lectures and laboratory testing for those who are engaged in engineering works. Many of the students who have attended these classes have received good appointments; for example, Mr. Arnot has lately gone out to Australia in charge of an electric tramway, &c., and Mr. Yeaman has been appointed Electrical Engineering Inspector for Liverpool.

NOTES.

The Popularity of the Electric Light.—As an evidence of the increasing popularity of the electric light in Berlin, the amount paid in royalties to the municipal authorities by the central electric stations was equal to £167 in 1885, £1,366 in 1886, £2,952 in 1887, and £4,739 in 1889. The royalties are 10 per cent. of the gross receipts.

Electric Lighting at Abroath.—At a recent meeting of the Police Commission and the Gas Corporation it was unanimously decided to oppose the Scottish House-to-House Electricity Company, Limited, in their application for a provisional order to supply electricity to the town.

Electric Light in Dumbarton.—The Dumbarton Dean of Guild Court, on Monday, granted permission for the erection of electric works on Helenslee grounds for the purpose of supplying the electric light to private dwellings.

The Electric Light in Aylesbury.—Messrs. Field and Sons, silversmiths, of this town, have recently carried out a small installation on their premises, consisting of 40 Edison-Swan incandescent lamps.

Electric Yachts in America. — A new electrical yacht made her trial trip in New York Harbour some few days ago. The boat is 36 feet in length by 3½ feet draught. Motive power is furnished by 200 storage batteries placed in the cabin lockers. A 10-horse motor, made by the Electro-Dynamic Company, of Philadelphia, drives the boat.

The Erection of Telephone Poles at Gosport.—At the last meeting of the Alverstoke Local Board it was agreed to adopt the recommendation of the road and works committee, and allow the Western Counties and South Wales Telephone Company to erect posts in their district, on condition that the work be supervised by the board's surveyor (Mr. Fry).

The Telephone in France.—The Paris correspondent of the *Daily News* says the Postmaster-General has published his telephonic tariff. Yearly subscriptions in Paris are reduced from £24 to £16, and in towns in which there is already an underground network of wires to £12, on the condition, however, that each subscriber shall bear a proportionate part in making necessary repairs.

The Proposed Telephonic Communication with Dunmore and Passage.—The *Waterford Chronicle* says the proposal to connect Waterford with Dunmore and Passage by telephone has fallen through in consequence of the high terms asked by the Post Office authorities. The local steamship companies were quite ready to join with the Harbour Commissioners in bearing part of the expense, and Lieut. Tipping, R.N., District Inspector Royal National Lifeboat Institution, strongly approved of the arrangement. In case of shipwreck the telephone would be of invaluable service between the three stations. Pilots, shipbrokers, and owners of vessels would also find it a source of convenience, and when so many would be benefited by the scheme it is a pity that it has fallen through.

The Electro-Harmonic Society.—The members of this society have already learnt that the first concert will take place on Friday evening next. After the serious business of the Paris Congress and the B. A. meeting it will be pleasant to meet one's friends under the soothing influences of the divine art and the fragrant weed. An excellent programme is in course of preparation, the musical directors and accompanist retain their positions as in previous years, and every effort will be made to make the 1889-90 season equal to, if not superior to its predecessors.

Honours to Members of the British Association.—About four hundred members of the Association took part in the excursion to Durham, and in honour of the visit the Senate of Durham University held a Convocation, when the honorary degree of D.C.L. was conferred upon the following gentlemen :—Sir F. J. Bramwell, Professor W. H. Flower, Professor A. W. Williamson, Captain Sir D. Galton, Dr. A. G. Vernon Harcourt, Captain W. De W. Abney, Professor J. Geikie, Professor J. S. Burdon-Sanderson, Colonel Sir F. De Winton, Professor F. G. Edgeworth, Mr. W. Andrews, and Professor W. Turner.

Electric Launches on the Thames.—A small party started in the Immisch electric launch, *Eta* from Hampton on Saturday, the 7th, for Oxford. It consisted of Mr. A. Rawlinson, of Brighton, Mr. Saunders, of the Miller of Mansfield Hotel, Goring, and Mr. Volk, manager of the Platt's Eyot Works, Maidenhead. The first stopping place, a distance of 26 miles, not counting the locks, was reached in about 14 hours, and the *Eta* was recharged during the evening at the charging station stationed there. On Sunday a little excursion with a few additions to the party was made to Medmenham and back, but on Monday morning the serious interest was renewed by running to Goring, 34 miles, where the *Eta* was recharged during the small hours of the night. 10 o'clock on Tuesday morning saw Goring left behind, and after two halts on the stream, Oxford was reached by 4 o'clock in the afternoon. During the two hours the *Eta* lay at Oxford, she was an object of considerable attraction, being the first electric launch that has been above Goring, and a large portion of the boating public, whose curiosity has been excited by the account and illustrations of these craft, had an opportunity of examining the handsome and attractive *Eta*. Leaving Oxford at 6 p.m., a stop was made at Abingdon for the night. Goring being reached by noon on Wednesday, a small charge was put in during lunch, after which the journey was resumed to Reading, which was left on Thursday morning at 8 o'clock, a short stay being made at Henley. Maidenhead, the end of the journey, was reached at 1 p.m. It is noteworthy that not only was no time lost in the recharging of the launch, which was effected during the night or at meal times, but also that 60 miles from Goring to Oxford and back was covered with but one charge of electricity. The *Eta* has therefore made two records, one for distance and another for work, and her owners have just cause to be proud of her performance.

The Telegraph on the Eiffel Tower.—The telegraph on the summit of the Tower has commenced work, and is exceedingly popular.

The Rating of Machinery.—An important and largely attended meeting of manufacturers from all parts of England was held on Wednesday last week at the Grand Hotel, Bristol (W. F. Fox, Esq., of Nottingham, in the chair), to consider the attempts which have been made to assess all kinds of machinery to the local rates, and to consult as to the steps which should be taken to protect the interests of all those affected. It was unanimously resolved that a national society for the exemption of machinery from rating be formed among the machinery users of the kingdom, for the purpose of assisting manufacturers to resist illegal and excessive assessments. It was also resolved to prosecute an appeal to the superior courts against the recent decisions of the Somersetshire Quarter Sessions in respect of the machinery in the mills in the Chard Union, and to promote a Bill in Parliament which shall declare the law and render it free from any doubt on the subject. Subscriptions were paid or promised, amounting to upwards of £2,000.

Electropathic Quackery.—The *Medical Press* says :—We understand that the little fee of three hundred guineas, which a certain electrical quack recently drew from the pocket of a well-known nobleman in return for medical services, has been refunded under threat of legal proceedings and exposure.

Personal.—Mr. Parsons, who had the management of the Sunbeam Lamp Works at the time when the superincandescent lamp, afterwards called the sunbeam lamp, was initiated and perfected, has, we understand, resigned all connection with the Sunbeam Lamp Company.

Mr. Henry Jackson, late telegraph superintendent of the Furness Railway, has been appointed telegraph superintendent of the Lancashire and Yorkshire Railway Company.

An Ingenious Device.—It is reported that an electric company in Chicago, by means of an ingenious device, is enabled to operate their ten ampère lamps with a current of only five or six ampères without causing the slightest hissing in the lamps or sparking at the brushes. The arrangement enables local lighting companies having city contracts to satisfactorily run the street lighting after midnight at a lower brilliancy at a reduction of 40 per cent. to 50 per cent. in the matter of fuel.

NEW COMPANIES REGISTERED.

Electric Wiring and Fittings Company, Limited.—Capital £5,000 in £1 shares. Objects : To manufacture and deal in dynamos, mains, batteries, lamps, chandeliers, wire cables, insulating materials, accumulators, leads, wires, conductors, brackets, electric bells, and other apparatus for the generation, distribution, supply, accumulation and employment of electricity. Signatories (with 1 share each) : E. C. Davidson, Twickenham ; Walter Harris, 136, Drayton Park, N. ; F. Wainwright, 6, Belmont Road, Wood Green ; D. Ruddle, F.G.S., 60, Delaney Street ; G. E. Lloyd, R.D.S., 238, Tottenham Court Road ; H. Cox, Ewell, Surrey ; J. Young, Surbiton Park Terrace, Kingston-on-Thames. The remuneration of the directors is to be appointed by the company in general meeting. Registered 11th inst. by Davidson & Morriss, 40 and 42, Queen Victoria Street, E.C.

Williamson Electrical and Engineering Company, Limited.—Capital £5,000 in £10 shares. Objects : To carry on in New South Wales, or elsewhere, the business of electrical and general engineers. Signatories (with 1 share each) : J. R. Williamson (electrical engineer), and J. A. Sharples, 14, St. Ann's Square, Manchester : J. Crewdson Waterhouse and V. K. Armitage, of Manchester ; G. A. Southam and S. Armitage, of Pendleton ; J. Platt, Sale, near Manchester. Table A of the Companies Act, 1862, will govern the affairs of the company. Registered 13th inst. by Needham, Parkinson & Slack, 10, York Street, Manchester.

OFFICIAL RETURNS OF ELECTRICAL COMPANIES.

Brompton Electric Fittings Company, Limited.—The statutory return of this company, made up to the 3rd inst., was filed on the 11th. The nominal capital is £2,000 in £1 shares. 650 shares have been taken up, and the full amount has been called and paid thereon. The registered office is at 146, Brompton Road, S.W., Basil Gee, manager.

Crompton-Howell Electrical Storage Company, Limited.—The statutory return of this company, made up to the 6th inst., was filed on the 11th inst. The nominal capital is £19,600 divided into six founders' shares of £100 each and 19,000 ordinary shares of £1 each ; the whole of the former and 12,007 of the latter are subscribed for. Upon 4,007 ordinary shares, 15s. per share has been called, the calls paid amounting to £3,003 15s., and unpaid to £1 10s. £600 is considered as paid upon the founders' shares, and £6,000 upon 8,000 ordinary shares. Registered office, Mansion House Buildings, Queen Victoria Street.

EXECUTION BY ELECTRICITY.

THE following letter has been addressed by Dr. R. Whittington-Lowe, of Brighton, respecting the extraordinary statements made by Mr. Preece before the B. A. Meeting at Newcastle. The New York correspondent of the *Daily News* also comments upon the manner in which Mr. Preece's unfortunate utterances have been received over there, and his telegram follows the medical man's letter:—

Sir,—I notice in the *Times* of to-day (17th) some remarks by Mr. W. H. Preece, chief electrician to the General Post Office, spoken at the meeting of the British Association on Monday, in which he refers to the late death by electricity at Brighton. As the medical man engaged in that case, I hope you will be able to spare room for a few hurried notes. From your report it appears that Mr. Preece made the statement that the electrical current had stopped running two hours before the death of the unfortunate man, thereby inferring that this could not be a death by electricity. This is altogether incorrect. The man was found dead at 6 a.m., lying about 3 feet below a wire which carries a current of 2,000-volt power, the said wire being pulled downwards from its position about 2 feet. The hands and face of the man, being uncovered, were cold, and he had probably been dead from an hour to an hour and a half, or thereabouts, which would fix the time of death between 4 30 and 5 a.m. I gather from the *Times'* report of Mr. Preece's remarks that Major Cardew was sent down by the Board of Trade to investigate the case, and so complete does the investigation appear to have been that I have heard nothing of it, nor have I been asked a single question as to the man's death. Mr. Preece's remarks seem to be based upon a statement made by some of the *employés* of the electric light company, to the following effect, viz.:—That at about 4.30 or 4.40 a.m. on July 15th there was a flash of lightning, followed by thunder, which caused so great a disturbance to the electric light company's works that the current was immediately interrupted and was not again set running, owing to the damage which had been done. Now, it follows that if the exact time of this accident to the machinery was, as here stated, not later than 4.40 a.m., and the man was alive later than 4.40 a.m., he could not have been killed by the electric current passing through the displaced wire. Here comes a little difficulty. The dead man was night-man at the brewery where he met his death, and had charge of the engine, the fires of which it is believed would not burn for longer than one hour without attention. The fire, although very low, was burning when the day workmen arrived at 6 a.m., so that, at first sight, it would seem that the deceased must have attended to the fire as late as 5 a.m., or 20 minutes later than the electric company's men say the current stopped running. To clear up this difficulty two things are necessary — first, that the time of the accident to the machinery should be proved exactly; and, secondly, it must be shown that the engine would not run for more than an hour without attention. Through the courtesy of Messrs. Hallett and Abbey, to whom the brewery belongs, I hope to have the latter point experimentally determined, and I think Mr. Preece had better undertake the proof of the exact time of the flash. There are several other points which Mr. Preece may possibly be able to clear away—first, what caused the wire to be pulled down 2 feet at the point where the dead man lay; second, what, in the absence of any sign of disease, after a *post-mortem* examination, was the cause of this strong young man's death; third, what caused the line of abraded skin on the side of the neck, which I, as well as all the jurors at the inquest, regarded as the consequence of contact with the wire; fourth, why the electric company offered the deceased man's widow £180 as compensation; fifth, why, when this sum had been declined, and an action is pending between the widow and the electric light company for heavier damages, the time of the lightning flash becomes more definite; sixth, why the electric company's solicitor at the inquest did not occupy such an unassailable position on behalf of his clients as Mr. Preece has discovered; seventh, and lastly, let me ask if Mr. Preece, since he considers that the wires may be handled with perfect safety, is prepared to give us a practical demonstration on this point by laying hold of this 2,000-volt electric wire, which without doubt killed the poor man on the early morning of July 15th, 1889.

New York, Tuesday.

The brief outline of Mr. W. H. Preece's remarks before the British Association on the subject of electricity as a means for the execution of criminals, which has been telegraphed over here excites much astonishment. He is represented as saying that the reports in the American newspapers of deaths due to shocks received from electric wires have been found on investigation to be nonsense. This statement is generally spoken of as being grossly inaccurate. There is scarcely a day, it is urged, on which such deaths are not reported on undisputed evidence. The victims usually are men employed in repairing or stringing electric wires upon poles. Throughout the city the number of such deaths on record since electric lighting became common is between 50 and 100.

Mr. Preece is also reported to have said that the New York law providing for the execution of criminals by electricity would have to be rescinded. It is unknown here what authority he can have for this assertion. The electric lighting companies are, it is true, seeking to have it repealed, but the weight of expert opinion, including Mr. Edison's, is in favour of the law and the system introduced by it.

CITY NOTES.

Halifax and Bermudas Cable Company, Limited.

THE capital of this company is £50,000, divided into 10,000 shares of £5 each. The objects are to establish lines of telegraphic communication between Halifax and Nova Scotia and points in Bermudas or elsewhere, as the company may determine. The English Government have agreed to pay a yearly subsidy of £8,100 for 20 years, which will be exclusively employed for the repayment of principal nnd interest. The following are the directors:—Sir Alexander Armstrong, K.C.B., F.R.S. (chairman of the Edison Gower-Bell Telephone Company, Limited), The Albany, Piccadilly, W.; J. W. Adamson, Esq. (of the late firm of Messrs. Adamson and Ronaldson), 26, Billiter Street, E.C.; L. H. Isaacs, Esq., M.P. (director of the Metropolitan District Railway), 3, Pembridge Square, W.; M. Mowat, Esq., merchant (late president of the Bombay Chamber of Commerce), 47, Granville Park, Blackheath; and J. Du Mont, Esq., 33, Old Broad Street, E.C.

The statutory meeting of this company was held yesterday at Winchester House, Sir A. Armstrong, K.C.B., in the chair.

The Secretary having read the notice convening the meeting,

The Chairman said: You are aware that this is a statutory meeting of the company, called in accordance with Act of Parliament. You will doubtless be interested to learn the progress of the company. We have concluded satisfactory arrangements with the Government, and in our various negotiations we have received fair and equitable treatment. As our future communications with the Government must be many and frequent, I look forward with hope that we shall receive the same support in working which we have hitherto done, and which will tend largely to promote the interests of the service in which both Government and ourselves are so deeply interested. The cable work is now progressing as rapidly as possible, and will be completed, presumably, at an early period. Nothing has been left undone which might increase the rapidity of work. We have appointed the eminent firm of engineers, Messrs. Clark, Forde and Taylor, who are sufficient guarantee that the work will be well and carefully done. The Government have also appointed the chief engineer to the Post Office to supervise the work, in addition to our own engineers. There has been a little unfortunate delay in the manufacture of the cable, but that has now been overcome. We are now in communication with the Government with regard to the points where the ends of the cables should be landed at Halifax and Bermuda. It is necessary that the cable should be laid under the protection of the guns of the fortress in both places, and we shall communicate with the Governor of Bermuda and the officer commanding the troops at Halifax with that object, and until we have received a reply we cannot say exactly where the cable will be laid. The Government have in Bermuda an admirable system of telegraphy; there is also a private firm of telephony; this will ensure communication through the island, and our cable will bring the means of communication with the mainland within the reach of everybody. The climate of Bermuda is remarkably fine, and has hitherto been the resort of the Americans; but there being no telegraphic communication has been a great drawback. That will be entirely overcome when we have this cable laid. The inhabitants of Bermuda look forward with eagerness to this cable being laid, and I think they will be greatly pleased when they find that the cable is in progress of manufacture. In addition to the advantages I have mentioned, there is a good port for steamers, a dockyard, coaling stations, and it is an important rendezvous for ships of the navy. There is in contemplation by a Canadian company the erection of a weather observatory. This will be an important feature, as it will enable Europe to know the course of storms in the Atlantic. Bermuda is 700 miles from the mainland, 60 hours' journey from New York. I think at the next meeting we shall have a very good account to give you.

In answer to questions, the Chairman said they had commenced the making of the cable, and had finished about 200 knots; they looked forward to it being finished before the end of the year. The Government would commence paying subsidies as soon as the first message was sent over the wire.

The Direct Spanish Telegraph Company, Limited.—

The Board have, upon the audited accounts for the half-year ended 30th June last being submitted to them, decided to recommend the payment of the dividend at the rate of 10 per cent. per annum on the preference shares, and a dividend at the rate of 5 per cent. per annum upon the ordinary shares (free of income tax).

TRAFFIC RECEIPTS.

The Brazilian Submarine Telegraph Company, Limited. The traffic receipts for the week ended 6th September, 1889, amounted to £3,048.

The Western and Brazilian Telegraph Company, Limited. The traffic receipts for the week ending 6th September, 1889, after deducting the fifth of the gross receipts payable to the London Platino-Brazilian Telegraph Company, Limited, were £1,911.

The West India and Panama Telegraph Company, Limited. The estimated receipts for the half-month ended the 15th September are £3,084, as compared with £2,490 in the corresponding period of 1888.

THE BROOKS SYSTEM OF UNDERGROUND ELECTRICAL CONDUCTORS.

ON Monday last, at the works of Messrs. Johnson and Phillips, Mr. David Brooks, of Philadelphia, conducted some tests of his system of fluid insulation over an experimental line in the presence of representatives of the electric light companies, the Post Office telegraphs and the technical press. Mr. Brooks's system was fully described and illustrated in our issue of February 3rd, 1888. At first the practice was to use lead tubes, but in 1887 a line, one mile and a third long, was laid between two stations of the Pennsylvania Railroad, in which iron pipes were substituted as being not only cheaper, but more stable and in every way preferable. The insulation of this line has increased since it was laid, and not one of the conductors has been interrupted for a moment. Recently Messrs. Johnson and Phillips, impressed with the efficiency and durability of the system, became sole licensees and manufacturers for the United Kingdom. The peculiarity of the system is, that while in a fault in ordinary insulation, the tendency of the current is to centre in that fault and increase the defect; the fluid insulation, on the contrary, automatically counteracts any defect. The experiments on Monday commenced with the testing of the insulation of a single conductor with all the others placed to earth, and then of the insulation of the whole of the conductors taken as that of an electric light cable. Afterwards the electric light was put on to a telephone circuit with a tension of 1,200 volts, the two wires being twisted together with 10 lamps in circuit to see if the insulation could be broken. The next test was to take the entire number of the conductors (7), and try the resistance of the insulation with a large size induction coil brought by Mr. Apps. This, in the air, gave a spark of 8 inches, but failed to destroy the insulation between the conductors as immersed in the oil. The results of these trials were considered in every way satisfactory. At their conclusion, Mr. Brooks and his friends, at the invitation of the representative of the Metropolitan Supply Corporation, paid a visit to the Deptford supply station and inspected the works.

ELECTRIC LIGHTING IN PADDINGTON.

IMPORTANT REPORT OF THE SPECIAL COMMITTEE.

Terms of the Lighting Companies.

IN the ELECTRICAL REVIEW of August 16th it was stated that a very valuable report on the whole subject of electric lighting was being framed by a special committee of the Paddington Vestry. Pending the completion of this report the consideration of the question of lighting the parish by electricity was adjourned by the vestry until after the recess. Their first meeting after the holidays was on Tuesday last, Mr. Churchwarden Jackson presiding, when the important report of the electric lighting committee as to the action to be taken by the vestry in the matter of supplying electricity for lighting purposes was submitted. The report was signed by the chairman of the committee (Col. H. F. Blair, R.E.) and the following members :— Messrs. W. Clarke, G. H. Maberly, W. Owen, W. Rayner, C. A. Stephenson, and G. A. Williams. These gentlemen stated that they had held seven meetings, and had devoted considerable attention to the subject of the action to be taken by the vestry for supplying electricity for lighting purposes in the parish. The committee had applied to the following companies for definite information as to the price at which they would be prepared to supply energy both for public and private lighting on the terms laid down in the model order :— The Electric Supply Corporation, Limited ; the Metropolitan Electric Supply Company, Limited ; the House-to-House Electric Light Supply Company, Limited ; Mr. S. Morse ; the Westminster Electric Supply Corporation, Limited ; the London Electric Supply Corporation, Limited ; and the Kensington and Knightsbridge Electric Supply Company, Limited. The special committee then reported as under :—

"As regards the best mode of public lighting by electricity there seems little doubt that arc lamps are the most efficient and least expensive. Mr. Spagnoletti, chief electrician of the Great Western Railway, entertains no doubt on this point. The installation under his charge in Paddington is one of the most successful experiments in public lighting. This installation supplies energy to 100 arc lamps of 3,000 nominal candle-power, and 4,000 incandescent lights. The real power of the arc equals at least 2,000 candles, and the light afforded is greater than would ever be required for street lighting. The object of the railway company is to enable all work to be carried on by night and by day with equal facility as far as light is concerned. To obtain the requisite illuminating power arc lights are placed at a distance of 75 yards from each other. Mr. Spagnoletti calculates that the annual cost of the admirable system arranged by him is not greater than would be that for gas at 2s. 9d. per 1,000 feet. The actual cost of public lighting by arc lights is difficult to arrive at, there being an extraordinary difference in the opinions of experts as to the number required for effective street lighting. Prof. Forbes calculates that the lights should be 80 yards apart, and that 21 arc lamps would be required for a mile of streets. Mr. Mackie, on the other hand, considers that 10 arc lamps per mile would be adequate. Mr. Slater, in his evidence before your committee, stated that the Galway Docks are most efficiently lighted by electricity, the arc lights there being placed, say, 150 yards apart. At Eastbourne 16 arc lights are set up on about a mile of beach, the posts being only 25 feet high, which is considered by the secretary of the Electric Lighting Company there to be too low. The best position for arc lamps would be at the intersection of streets, in order that the light may be visible for at least 100 yards in each direction, north, south, east and west ; arranged in this manner it is probable that 12 arc lamps would not only completely light one mile of main streets, but afford light for about 100 yards in streets crossing the main line. The arrangements at Hastings are identical in all respects with those of Eastbourne. At Taunton the arc lights run for an average of eight hours, at an annual cost of £22 10s. per light. It is impossible to calculate the cost of street lighting on a large scale, but the greater the consumption of energy the smaller would be the relative cost. The secretary to the Eastbourne Electric Lighting Company informed Mr. Minchin that energy could be supplied for 40 public arc lights at only 20 per cent. greater cost than that of the 16 now used by the town at an expense of £30 per light. Taking everything into consideration it would appear advisable for the vestry to entrust the work of electric lighting to a well-established company, and in view of the possibility of the local authority desiring to purchase at any future time the undertaking of any company in the parish, your committee consider that it should be a *sine qua non* that the central stations for the production and supply of electricity should be constructed, and the distributing mains laid, so as to form a complete installation, for Paddington, independent of all connection with other parishes. In conclusion, it may be observed, from the evidence adduced before the House of Lords, that the continuous system, in conjunction with storage batteries, as supplied by the Chelsea Company, is considered preferable for private lighting."

After giving at length the correspondence which had taken place with the Board of Trade with the view of securing the insertion in the model order of clauses to protect the rights and interests of the vestry as the local authority—which protective clauses had been adopted by the Board of Trade—the committee stated that the following were the questions asked by Mr. F. Dethridge, the vestry clerk, on behalf of the committee of the various electric lighting companies above mentioned :—

"1. At what price you will be prepared to supply energy for public lamps, and the mode in which the charge will be ascertained.

"2. To what class of lamps for street lighting is your system applicable.

"3. The quarterly charge to be made to private consumers for electricity supplied per Board of Trade unit, stating clearly how such charge will be arrived at in proportion to the number of hours' consumption in each case of the maximum supply applied for by each consumer, adding the cost of rent of meter quarterly."

The Vestry Clerk also added that preference might probably be accorded to such company as, other advantages being equal, would confine its operations within the limits of Paddington, so as to facilitate at any future period the purchase of the works by the local authority.

In reply to these questions, answers were reported by the committee as having been received from Mr. Sydney Morse; the Westminster Electric Supply Corporation, Limited; the House-to-House Electric Light Supply Company, Limited; the Electricity Supply Corporation, Limited; and the Kensington and Knightsbridge Electric Lighting Company, Limited.

Mr. Morse, in his letter, wrote:—

"1. My clients will either be prepared to supply energy to public lamps at 8d. a unit or by special agreement, but I must point out that until the question whether my clients are to treat on the basis of an order for the whole of the parish or for part only has been determined, it is impossible to give a more definite answer as to what agreement might be arranged with you.

"2. The system to be adopted is applicable to all classes of lamps, both arc and incandescent.

"3. In reply to 3, my clients will propose to charge in accordance with the amount of electricity supplied, as certified by a proper meter (rented at, say, 5s. a quarter).

"The quarterly minimum charge would probably be 25s., but, if the minimum is meant by the question, to be in proportion to the maximum, my clients consider that if the maximum required per quarter is 100 units, the minimum should be 40, and so on in proportion."

Mr. Frank Iago (the secretary of the Westminster Electric Supply Association, Limited) replied:

"1. We are prepared to supply energy for public lamps at sixpence per unit.

"The charge could be estimated by measuring the exact quantity of energy supplied by meter, or by a calculation based on the amount of current required to burn the carbons at any specified candle-power your vestry may desire the lamp to give, and the number of hours the lamps would be in operation. A monthly, quarterly, or yearly rate would be quoted when our Board are in possession of your requirements. It is suggested that it would be desirable for your vestry to appoint a committee to inspect our lamps for street lighting before coming to any decision.

"2. The company will undertake to supply current adaptable for any class of lamp your vestry may decide upon.

"3. The company are prepared to charge private consumers, either at a fixed charge per light, to be hereafter agreed upon, or by meter at 8d. per unit, charging to an ordinary consumer for meter rent, 5s. per quarter.

"The company are prepared to erect works in Paddington, and to keep separate accounts so as to facilitate at a future date the purchase of the works by the local authority."

On behalf of the House-to-House Electric Light Supply Company, Limited, Mr. H. St. John Winckworth wrote as under:—

"1. The price at which we shall be prepared to supply energy for public lamps would be in accordance with the provisions of the provisional order granted to us by the Board of Trade, which has been fixed for the whole of London at the rate of 8d. per Board of Trade unit of electricity supplied. Although we should be quite willing to reduce this price very considerably, owing to the long number of hours the public lamps are burning, we are afraid that clause 20 of the Electric Lighting Act, 1882, prohibits us from so doing. The enclosed scale of charges, which we are at present adopting at Kensington, and is in use at Eastbourne, would work out equal to about 4½d. per Board of Trade unit for public lighting. The mode in which the charge for electricity will be ascertained, is by the use of an accurate meter.

"2. The system this company has adopted at Kensington is applicable to either arc or incandescent lamps.

"The quarterly charge to consumers would, we presume, be at the rate of 8d. per Board of Trade unit, in accordance with the provisions of the model provisional order issued by the Board of Trade, irrespective of the number of hours' consumption, and the maximum supply demanded.

"Our charge for rent of meter, instruments, &c., is 3d. per light per quarter. This company would be quite willing to establish a special electric lighting station for the parish of Paddington, in order to facilitate at any future period the purchase of the works by the local authority. As, however, the Board of Trade have granted to this company a provisional order to light the northern portion of Kensington, adjoining the parish of Paddington, we should probably prefer to place our electric lighting station within this parish, in order to obviate any nuisance which might be caused to the residents of Paddington, by the establishment of a central station within the district."

The reply of the Electricity Supply Corporation, Limited, was:—

"1. Energy for public lamps, if within the area of private supply, will be supplyed at 25 per cent. at least under the rate charged to the public, subject, however, to this condition:—that the price shall not be an undue preference within the Electric Lighting Act of 1882.

"2. The E.P.S. system is suitable for all classes of public lighting, whether by arc, high candle-power, glow, or ordinary incandescent lamps.

"3. The minimum quarterly charge for electricity will be 13s. 4d., and the maximum price per Board of Trade unit will be 8d. The amount will be arrived at by certified electricity meters, added to a rental of about 3s. per quarter per 100-light meter.

"4. The whole of the works to be executed under the Paddington provisional order, will be erected in the parish of Paddington, and we are willing to conform to all reasonable demands of the vestry."

Mr. R. S. ERSKINE, the secretary of the Kensington and Knightsbridge Electric Lighting Company, Limited, replied to this effect:—

"1. At 10 per cent. discount off the price we charge to private consumers under our present licence, which is 8d. per Board of Trade unit of 1,000 watts per hour.

"2. Either to large incandescent or to arc lamps. The former may be of any candle-power up to 200. The latter, from 500 candle-power upwards, as may be asked for.

"3. We do not make a quarterly charge, except in the sense that we send quarterly accounts for the quantity of electricity used, measured by meters fixed in the consumers' premises.

"Our meter rent varies from 5s. a quarter upwards—

5s.	a quarter,	meter	suitable for	36 10-C.P. lamps.
6s.	"	"	"	75 10-C.P. lamps.
10s.	"	"	"	150 10-C.P. lamps.

"4. In case this company succeeds in obtaining powers to light Paddington parish, it would be prepared to put down a separate generating station and complete system for the parish, which might be worked in combination with the existing Kensington and Knightsbridge stations, or not, as may be hereafter desired."

In addition to the reply to the questions asked on behalf of the vestry, the letter of Mr. Winckworth contained a long and interesting enclosure as to the terms of supplying electricity to private consumers. Particulars being given of the supply and cost of light, of

renewal, and of fittings. As to the advantages of the electric light the enclosure gave the under-mentioned useful facts :—

"It is admitted on all hands that our houses are not at present satisfactorily lighted. The excessive heat of our rooms at night is a subject of universal complaint, and the injury to health and eyesight, and the damage to books, pictures, decorations, &c., by ordinary illuminants, is a formidable objection to their use.

"It can unhesitatingly be claimed that by the use of the electric light, supplied from central stations, the whole of the disadvantages connected with lighting by other means can be done away with. It may, indeed, be justly considered a perfect light, since it will stand the test of *purity*, *cleanliness*, *coolness*, *convenience*, *steadiness*, *beauty*, *and safety*.

"Purity, Cleanliness, and Coolness.—The greater or lesser brilliancy of the light from other illuminants depends upon the greater or lesser amount of oxygen (which is the one ingredient in the atmosphere necessary to sustain life) which they abstract from the air. In the production of light by their use, oxygen is used up (*a*) in combination with hydrogen in the burning flame, and (*b*) in combination with carbon, the particles of which, when raised to incandescence, give out the light.

"The result of the first-mentioned chemical action (*a*) is the formation of vapour, which, being dispersed through the rooms, is condensed in the form of water, and deposited on the walls, ceiling, carpets, furniture, books, pictures, &c. The result of the second chemical action (*b*) is the formation of carbonic acid, to the presence of which in our rooms at night may be traced many of the ailments with which adults are afflicted. Six gas jets in a room of average size produce more deleterious effects on the atmosphere than thirty human beings, each jet consuming more pure air than five persons.

"Moreover, a certain number of carbon particles pass unconsumed through the flame, and settle down in the form of smuts. These, and the fumes of sulphuretted hydrogen and carbon disulphide, given off by gas, blacken ceilings, wall paper, furniture, &c., and tarnish gilding, silver, &c.

"On the other hand, the incandescent electric light produces no such effects, for the reason that it is obtained by the heating to incandescence of a thin filament of carbon contained in a glass bulb hermetically sealed.

"There are some who object to the electric light on account of its coolness, and who say that gas is of service in a house for the purpose of heating the rooms. But when people realise that gas can only raise the temperature *by distributing noxious fumes*, they will prefer to heat their houses by more healthy methods."

Having quoted the remarks at the British Association of Mr. W. H. Preece as to the beauty and hygienic qualities of the electric light, the letter pointed out the convenience of turning the current on and off, and its steadiness, and then proceeded thus to refer to its beauty and safety :—

"*Beauty.*—It is sometimes urged that a room never looks so well as when it is lighted by wax candles, or by oil lamps suspended from the ceiling, but though architects have been slow to treat the artistic arrangement of incandescent lamps, they are now awakening to the fact that they are capable of the most artistic handling. In themselves they are beautiful objects requiring little external decoration, and, where care is exercised, the most pleasing effects may be produced. They may be hung from the ceiling by silken cords, which conceal the wires conveying the current, or placed in the centre of sconces on the walls so as greatly to add to the artistic effect of the rooms. The wires conducting the electricity may be entirely hidden, but when exposed they are not more unsightly than the wires or cords by which pictures are usually hung.

"*Safety.*—Though the gas industry has been in process of development for more than fifty years, serious accidents through its use occur almost daily ; indeed, the frequency of their recurrence causes little attention to be paid to them, and the Press satisfies itself with very meagre reports of calamities which have long ceased to be novelties. Houses are frequently burned to the ground from the ignition of escaping gas, the upsetting of oil lamps, or the careless use of matches and candles. In the case of the electric light explosions and accidents of this kind cannot possibly occur.

"In the early days of the electric light much importance was attached by its opponents to the danger arising from the touching of wires conveying the electricity ; but the incandescent lamps used in house lighting can only take a *low tension current*, which is absolutely innocuous. Not only so, but the wires are necessarily carefully covered throughout with an insulating material, making it impossible for any one to come into contact with them.

"With regard to the danger of fire, the insurance companies consider that premises lighted by electricity are much safer than those otherwise lighted. The lamps can be placed in any position and used in any place, even in close proximity to combustible materials, such as cambric, muslin, or bed curtains, without doing any harm and without incurring the slightest risk. If, by any accident, a lamp be broken, the oxygen of the outside air rushes in and instantaneously extinguishes the light before even the most inflammable material can be set on fire."

The special committee, in their report, also included a letter received from Mr. A. W. Slater, electrical engineer, giving his reasons for recommending that the vestry should undertake both the public and private lighting of the parish. Those reasons were :—

"1. To keep the streets and roads entirely under the control of the vestry.

"2. To secure economy to the consumers, as all the office expenses, &c., of a public company would be saved, and to a certain extent the necessary work of collecting the rates, &c., would be done by the vestry's present officials.

"3. To enable any profit which might result to be used to reduce the ordinary rates on the whole parish, as is done in Belfast and other large towns in the case of gas lighting, and in this way attract new residents into the parish.

"4. The parish of Paddington being, perhaps, the wealthiest parish in London, it should be the most paying place for electric lighting, or, in other words, the light should be far cheaper than in any other part of the metropolis, if undertaken by the vestry, who have no directors or dividend to pay.

"5. In the case of gas lighting, is is almost invariably found that when the works are in the hands of the local authorities the quality of the gas is excellent and the supply very good. This should apply with regard to electric lighting."

Mr. Slater further stated that in such a populous and wealthy parish as Paddington he believed that electricity could be supplied to private consumers at a rate equal to 4d. to 5d. per Board of Trade unit, and that Paddington was particularly well suited for the supply of electricity from a central station.

The very important report of the special committee concluded with a copy of a letter addressed to the authorities of Hastings, Brighton, Eastbourne, Taunton, and Exeter for any information they could give on the subject, and the replies received from those bodies.

Mr. J. I. Minchin proposed : "That the report of the electric lighting committee be received, and that the same be considered at a special meeting of the vestry on Tuesday next."

Mr. W. Clarke seconded the resolution, and it was carried.

Electricity in Pennsylvanian Mines.—The New York correspondent of the *Manchester Courier* says that electricity will be shortly used as a means of traction at the bottom of the mines. At the Erie Colliery of the Hillside Coal and Iron Company in Forest City a dynamo has been fixed for this purpose, and the railway will shortly be in operation.

INTERNATIONAL CONGRESS OF ELECTRICIANS HELD AT PARIS, 1889.

(*Continued from page* 307.)

Standards of Capacity.

THE standards of capacity are condensers graduated in microfarads and fractions of a microfarad; they are formed of sheets of tin, or sometimes tinfoil, alternating with sheets of some insulating material. This insulating substance varies according to the constructors; those most often employed are mica, paraffined mica, paper paraffined or covered with other insulating materials, and, lastly, ebonite cut into thin sheets.

The standards of capacity are as yet much more imperfect than the standards of electromotive force. They nearly all present, in a greater or less degree, three defects: 1, the charge is not rigorously in proportion to the difference of *potential* at the terminals; 2, they retain a residual charge; 3, the insulation is imperfect. Moreover, the capacity varies somewhat rapidly with the temperature.

When a condenser retains a residual charge its capacity is only clearly defined in two cases: that in which the discharge succeeds the charge with sufficient rapidity for the penetration of the electricity into the dielectric to be *nil*, and that in which the charge lasts sufficiently long for the penetration to have reached its maximum. But in the use of condensers it is often difficult to realise these conditions. In particular, if we wish to measure the charge of the condenser, on sending it through a galvanometer, by the impulsion of the needle, we use a formula which is only accurate if the discharge is produced in a sufficiently short time for the needle not to be appreciably displaced during its duration; now this is not what takes place if the penetration reaches its maximum, the total discharge requiring a time comparable to that of the charge.

The only condenser that could really be considered as a standard would be a condenser with an air plate. Unfortunately, it seems difficult to realise conveniently condensers with a plate of air having a capacity of the order of the microfarad; two circular trays, 60 centimetres in diameter and ·025 centimetres apart, form a condenser equal to about $\frac{1}{100}$th of a microfarad.

The determination of the absolute value of a capacity in electro-magnetic units is most frequently effected by methods in which the measurement of the capacity is reduced to the measurement of a resistance and of a time, such as the Maxwell method,* or its modifications, by J. J. Thomson † and R. T. Glazebrook, ‡ or else by methods in which the measurement of the capacity is reduced to that of a resistance and of a coefficient of mutual induction, such as that employed by M. Rïöti in his study of various condensers that had figured in the Universal Exhibition at Antwerp.§

The measurements by M. Röiti and other physicists show that the real value of the capacities in commercial use rarely differs from their nominal value less than 1 per cent., and that often the error amounts to 4 per cent.

Before bringing this report on electrical standards to a close, we should like to make a suggestion. The standards of mutual induction, resistance and intensity of current, which we have called *principal standards*, because their absolute value can be determined independently, without having recourse to other electrical standards, possess, when properly constituted, an invariability comparable to that of a standard of length or volume. The necessity of fixing a legal standard of resistance has been recognised; why is it not the same with the two other principal standards?

The question is especially of importance as regards the intensity of currents, and now the way seems to be sufficiently paved for it. The International Bureau of Weights and Measures possesses already prototype standards of length, volume, and electrical resistance; everything seems ready for the adoption of a balance electro-dynamometer, which would serve as a prototype standard apparatus in the measuring of intensities, and with which the other instruments might be compared.

The currents measured by the prototype electro-dynamometer, according to the formula $i = A\sqrt{p\,g}$, in which A represents the constant of the instrument determined by measures of length, would be estimated by a conventional ampère, which would only differ from the theoretical ampère by a quantity certainly less than the difference between the legal ohm and the theoretical ohm; it is very probable that this difference would be less than $\frac{1}{1000}$th. We should besides be able to control this error by the difference between the indications of this instrument, and those of M. Pellat's absolute electro-dynamometer.

Many would think that it would be simpler for the comparison of currents, to indicate the mass of silver deposited in a second by an ampère. We may remark that the conventional ampère thus fixed would not be defined with sufficient exactness; electrolysis is, in fact, an exceedingly delicate operation, involving causes of relative error at least 10 times as great as the comparison of two balance electro-dynamometers. We will give the last results obtained for the electrolytic equivalent of silver:

	Mass of silver in milligrammes deposited per ampère in a second. Milligrammes.
F. and W. Kohlrausch *	1·1183.
Mascart †	1·1156.
Lord Rayleigh ‡	1·1179.
Messrs. Potier and Pellat § ... 1st detn. 1·1189 mmg. 2nd „ 1·1195 „	1·1192.

Now the discrepancies which we note between the results in this table do not greatly exceed those which the same experimentalist finds in two electrolytic operations made under conditions as similar as possible as to measure of intensity, density of current, concentration of the solution of azotate of silver, &c. On the contrary, we have already said that the comparison of two balance electro-dynamometers can be made with a degree of precision within $\frac{1}{1000}$th. This fact clearly shows the inconvenience of the definition of a conventional ampère based upon electrolysis.

MEASUREMENTS OF ENERGY.

Report of M. A. POTIER.

Chief Engineer of Mines, and Professor at the Ecole Polytechnique.

At the time when dynamo-electric machines made their appearance in industry, the measurement of their rendering was of quite secondary importance and purely theoretical. We merely required from them services that a sufficiently powerful battery might have rendered, and their superiority from all points of view was so evident that little trouble was taken to measure it exactly; and even now, in a large number of installations the power expended by the machines intended for lighting is only a small fraction of the motive force of the factory, the excess of expense corresponding to a smaller rendering of the dynamo is swallowed up in much greater expenses amongst which it disappears, and all that is required of the machine is absolutely regular working. Now that the applications have become more numerous, and the distribution of energy to a distance has been conceived, now that special motors have been created instead of utilising forces which were, so to say, superabundant, and a more active concurrence has arisen among the different types of

* "Electricity and Magnetism," sec. 776.
† *Phil. Trans.*, vol. 174, p. 707 (June, 1883).
‡ *Phil. Mag.*, p. 98 (1884).
§ *Il nuovo cimento*, Vol. XVI., p. 175–180.

* *Sitz. des Phys. med. Ges. zu Wurtzburg* (1884).
† *Journal de Physique*, 2nd series, Vol. I., p. 100 (1882), and Vol. III., p. 283 (1884).
‡ *Phil. Trans. of the R.S.L.*, Part II., p. 411 (1884).
§ *Société Francaise de Physique*, March 15th, 1889.

machines, the rendering has become one of the factors of the commercial value of dynamos.

Thus it now becomes expedient to define this rendering exactly, and to agree as to the methods by which it is to be measured.

We will call the rendering of a dynamo machine, whether receiver or generator, the ratio of the available energy to the energy expended; the electrical energy will then be measured at the terminals of the machine; as to the work, it is desirable, in order to avoid uncertainties occasioned by the transmissions, that it should be measured on the axle of the machine.

The rendering of a motor can generally be measured with accuracy; except at very great speed, the employment of the brake will give very exact indications if we take the requisite well-known precautions concerning its sensibility and its tarage; the electrical measurements may be made with a yet closer approximation than that given by the brake. The rendering of a generator is also easily measured when we have at our disposal a proper transmission dynamometer; unfortunately these complicated and costly apparatus cannot be obtained at a moment's notice like brakes, their indications may be falsified if the speed exceeds certain limits, so that each apparatus works usefully only within somewhat narrow limits of power. Moreover, the dynamometers by which we measure the difference of tension of the two straps of the belt do not seem very exact.

It has therefore been sought to determine the renderings of generators without having recourse to these dynamometers, especially for machines of great power. We may proceed by substitution; after having taken at the Watt indicator the diagrams giving the work of the steam upon the piston at different rates of working and the electrical power of the dynamo, we replace this latter by a pulley with a brake on which we proceed in the same manner. Admitting that the rendering of the steam engine and of the transmissions remains the same, with powers and speeds that we endeavour to make as equal as possible, we have the elements necessary for the calculation of the rendering of the dynamo. When we have to do with a system of two machines, the determination of the rendering may be obtained by Messrs. Hopkinson's method: the two machines are mounted on the same axle and connected electrically like two batteries in opposition, so that one works as generator and the other as receiver; a dynamometer, which may be of low power, measures the work transmitted to the system of the two machines, work which is entirely absorbed by the passive resistances, the parasitic currents and the heating of the wires of the machines. This method has been modified by Mr. Revenshaw, who suppresses the dynamometrical estimation of the work transmitted. For this purpose a third dynamo is introduced into the circuit of the two first, and is worked by the motor. The power which it supplies is estimated electrically. If we designate as C this third machine, and as B and A the two first, which are mounted on the same axle, the measurement of the ratio of the differences of potential at the terminals of the machines, A and B, gives the rendering of the system A, B. Let R_3 be this rendering, we should in the same way determine by the simple comparison of two electrical measurements the rendering, R_2, of the system of the machines, A and C; and lastly, the rendering, R_1, of the system, B, C. If we call r_1, r_2, r_3 the individual renderings of the machines, and, supposing that they are the same in the three experiments, we shall get $r_1^2 = \frac{R_2, R_3}{R_1}$. It seems doubtful whether this method can lead to exact results, for the rendering of a machine varies with the intensity of the current that traverses it, and with its speed; it does not seem possible to make the machines work in these three experiments at their normal charge and speed.

M. Fontaine has employed a more simple method, also based upon the employment of three machines; the machine, A, is mounted on the same axle as the machine, B; the latter works as receiver, the current is sent into it by a third machine, C, but the machine, A, is outside the circuit, B, C, and closed upon a circuit of resistance variable at will. The resistance of this circuit is so regulated that the current is the same as in the circuit, B, C; the ratio of the differences of potential at the terminals of the machines, A and B, still gives the rendering of the system, A, B. When the two machines are identical in construction, M. Fontaine assumes that the rendering of each is the square root of the total rendering; this amounts to assuming, as is done in the modes of proceeding derived from the Hopkinson method, that the rendering is the same whether the machine is a generator or a receiver; with this hypothesis, it would be easy, by making three experiments, to determine the individual rendering of each machine. The two methods (Ravenshaw and Fontaine) seem very satisfactory, at least for the rapid comparison of the renderings of machines of the same type tried successively; but from the moment that the equality of the renderings is assumed the employment of transmission dynamometers becomes useless, and the trial at the brake ought to suffice when it is required to determine the rendering of a single machine. One reservation is, however, necessary on this point; it is not allowable to say that the rendering is the same for two similar machines working under the above conditions. The rendering of the system of two machines may be *nil*, for example, without that of the receiving machine that it works being *nil*; it seems more rational to admit that with equality of the magnetic field of the inductor, and of current in the armature, the losses due to parasitic currents and other causes are the same if the speed is equal. In M. Fontaine's method, for instance, if $\frac{100 - x}{200}$ is the rendering of the system, B, A, formed of two similar machines, the rendering of the receiver, B, should be $\frac{200 - x}{100}$, and that of the generator, A, $\frac{200 - 2x}{200 - x}$.

To carry this reasoning further, if $\frac{100 - x}{100}$ is the rendering of a receiver, its rendering as generator, under the same conditions, would be $\frac{100 - 2x}{100 - x}$.

If experiments made with care confirmed these conclusions, no series of trials at the brake—trials which mechanicians consider as susceptible of very great precision—would be sufficient to determine the renderings of a generator in the various conditions under which it is required to work. It would then be interesting to know within what limits we may consider as equal the renderings or the losses of the same machine working as motor or as receiver.

In workshops where several machines are at one's disposal, it would always be possible to determine the rendering of a generator without employing any transmission dynamometer. Experiment has shown that up to 50 H.P. at least, the maximum power that I have been able to try, a receiver is an excellent dynamometer. If we measure at the brake the work furnished by the dynamo, we always find within the limit of error the same rendering when the machine works under the same conditions of speed and charge, although the electromotive force is susceptible of slight variations; the machine being in its normal condition as to greasing. We may then take a receiver, and for a series of speeds form a table of the rendering corresponding to a series of intensities; this graduation being made with all possible care, the trial of a generator would be made simply by coupling it on the axle of the receiver, and comparing the numbers of watts furnished and absorbed by the two machines. It is evident that this method would be equally applicable to the measurement of the rendering of an alternating current machine; it has the evident advantage that the forces applied to the machine to be tried are

reduced to a couple merely. By the suppression of the belts we eliminate the error, which it is impossible to estimate, arising from the variable tension of that organ of transmission, and which the employment of dynamometers allows to remain.

If, on the occasion of the Universal Exhibition, competent persons prepared themselves to exchange their views on this question of rendering, and could arrive at the fixing of some uniform rules, it would be a great advantage to the constructors of machines, and to those who use them.

TELEPHONY.

Report of M. de la TOUANNE, *Telegraph Engineer*.

Telephony has, by wonderful good fortune, spread in less than 10 years over the entire world, and the instrument, received at first as a scientific toy, has become the foundation of an industry that extends its domain from the village to the most flourishing towns. But the very rapidity with which this industry has been developed is in itself a source of danger. Hardly has one system been adopted when another more practical and more ingenious is conceived, and we see in such and such a large town a company, mindful of its good reputation and of the services that it has to render, relinquish a system that was hardly fully established, abandon installations only just completed, in order to arrange the organisation afresh from its very basis and create anew, in all its details, a system in harmony with recent progress. Such a determination is only very exceptionally necessary; and if, in smaller proportions, these difficulties are every-day ones, they might in many cases be avoided by more frequent consultations amongst those who are charged with these enterprises; questions concerning the lines, apparatus, central stations and tariffs take a hundred different aspects, and while feeling our way as we are doing at present, it would be of great advantage if competent persons could consult together upon the solutions already attempted and on those already acquired. As to lines, it seems as if the question of the conductor is almost decided. Little by little copper and its alloys are being substituted for iron and steel. But still it is necessary to determine in what cases it is certainly advantageous to know the results obtained under the most varied circumstances possible with bronzes, with hard copper, and with annealed copper. The latter, owing to its feeble tenacity, seems reserved for cables, but even these have probably not arrived at their definite form. A large number of types have been proposed; but what are their precise specifications, advantages, inconveniences? What is practically the limit of resistance, of capacity? How many wires is it expedient to unite in a single cable? What modifications must be adopted in the fabrication of the cable according to whether the system is one of simple wires or of metallic circuits? What information does experiment give us on this point? With regard to these metallic circuits, what are the devices of construction employed in overhead systems? Is it not possible, as has recently been proposed, to reduce the number of conductors and to employ a single return wire for a group of wires on the single distance. In this case, what arrangements must be chosen as regards the juxtaposition, on the same supports, of several similar groups, &c. These are questions to which we shall obtain no answer worthy of credence unless a certain number of practical men, resting as far as possible upon facts, will discuss them fully, and relate their failures as well as their successes.

The apparatus do not give rise to so many different questions—that is, at least, if we abide by the results that are stated. Microphones, telephones, auxiliary signals, come under only a few categories. The manifold models due to the fertility of imagination of inventors could only with difficulty be compared and classified; often the differences between them consist of some detail of merely commercial interest. The microphones derived from the Hughes type have the very great advantage of being regulated once for all; those suggested by the Edison microphone are nevertheless retained in many systems; and lastly, the grain microphones were for a little while considered as an improvement. If the exact methods of measurement, now being studied, do not give, after a short delay, complete results, it will be desirable that the qualities of each kind, as observed by daily use, should be clearly stated.

Telephones have also exercised the spirit of invention; the principle being known, the different forms of electro-magnets had necessarily to be tried; the inventors might frequently have even avoided presenting certain forms as new if they had consulted former works on electro-magnets, those of Nicklès for example. In fact, at the present moment we believe that there are in existence several models of telephones very similar in value, and all good when they are well constructed. It is desirable, for the sake of future progress, that the exact relative influence of the parts constituting the instrument should be determined.

The auxiliary signals, bells, annunciators, &c., are modifications, sometimes happy, but not of capital importance, of telegraphic apparatus tried long ago. The same may be said of many combinations in which these accessories intervene—the Wheatstone bridge, differential mounting, &c., which have their origin solely in telegraphy; whether it a question of a Morse instrument, a bell, or an annunciator, there is no novelty in the matter. Innovation, which might be fruitful, appears very rarely, except in combinations where it is required to connect several consumers with the same wire of the central station, or in arrangements intended to procure communication with this latter automatically, after payment of the sum demanded for a conversation.

Amongst the accessories, one of the most important, the battery, is, perhaps, the one that leaves most room for doubt; the determinatiou of the most favourable element for transmissions would be useful.

With regard to the central stations, several points deserve special attention. In the first place there is the question of commutating tables; what facilities ought they to offer specially? For what number of consumers ought a central station to be furnished with that admirable system of multiple commutators which, coming originally from the new world, is gradually spreading over the old? These are elements, the knowledge of which is indispensable; the simplification and the certainty of the operations required of the *employé* are of capital importance when these operations are repeated several hundred times a day. The expense of the first installation then becomes secondary; indeed, often the greater part of the cost is more apparent than real. In any case, if it must be bought at the price of a temporary sacrifice, rapidity, which is the *raison d'être* of the telephone, is the first thing to obtain. And the diversity of the systems is such, that, according to the type of table adopted, the number of communications established by an *employé* has increased from 200 daily to 200 an hour. These figures are not exaggerated, the maximum is higher still. Under these conditions, we can see that special care must be taken in the choice of material for a central station. Nevertheless, the fruit of this labour of installation would be partly lost if jndicious regulations did not ensure a good utilisation of it; it would therefore be very interesting to compare the regulations observed in the different systems, the instructions given, as much to the correspondents as to the *employés*, and to know the advantages or inconveniences which experience has shown in their application. To mention one detail only, in the New York system, every demand of communication is held to remain valid until it is satisfied; in the greater number of other systems it has to be renewed by the person concerned, when he has been informed that his order could not immediately be carried out. Of the two systems, the first gives correspondents an apparently incontestable advantage; but we must at the same time consider to what degree it impeded the service to the detriment of the fresh demands for communication;

moreover, it seems only reasonable that at the end of a certain time the applicant should give up his turn for communication; the arguments for or against could only be furnished by those who have tried both systems. This particular point, be it understood, is mentioned solely as an example, and only shows the different points of view from which competent men judge, and the uncertainties which still prevail.

Another cause of the prosperity or failure of telephonic enterprises is the scale of charges adopted. Like every other industry, the telephonic industry seeks, in the first place, a *profitable tariff*, one which, by the combination of the number of communications and the payment demanded for them, gives, when all the expenses are deducted, the maximum of profit on the capital sunk. The estimation of the expenses is difficult to make in a general manner; they depend not only on the material employed, but also on local circumstances; in each particular case, however, this is an element which can be known with a certain degree of exactness; the second element, the cost of maintenance (? la loi des débouchés), according to which the payment is regulated, and also the number of communications or the number of subscribers is completely unknown; the preconceived ideas on this subject are almost always erroneous. It would therefore be a most interesting study to fix this definitely, but unfortunately the first data can very rarely be obtained. Most frequently the charges are fixed and modified without any preconceived plan; the lowering of them (we do not speak here of rises, which are the exception) are made by sudden, irregular leaps, and it is very difficult to seize the relation between the lowering of the tariff and the increase of the consumption. The information to be gained from the comparison between the size of the population and the number of subscribers is not of much account. For one single town, the signification of the figures of these far too concise statistics depends on several circumstances; the time the system has been established, the time during which the last tariff has been in operation, on the regularity of the service, all of which points are generally passed over in silence. If, on the other hand, we wish to compare the results obtained in different localities we require to know the character of the inhabitants, the nature of the social relations existing between them and resulting from their ordinary occupations, the climate, wealth, and the nature of the mercantile operations. Up to the present the telephone is above all a commercial instrument, and it would probably be easy to place in a distinct category the towns in which it is merely of social interest; but amongst the others it would be important to compare those which are really comparable; where industrial or commercial towns are concerned it would be best, in the first case, to distinguish from amongst the industries those that give rise to few transactions, but those few important from the sums involved, and those in which there is constant buying and selling requiring comparatively small disbursements only; with trading cities it is necessary to have a criterion of the activity of exchanges. These data, compared with those relating to the value of money in the countries under consideration and those figuring in telephonic statistics, might perhaps enable us to conjecture, knowing these causes, what probable development would be in store for telephonic industry in such and such determined circumstances. Without this methodical procedure we should only, according to all appearance, find uncertainties or disappointments equally fatal to the initiative spirit. The problem is, moreover, a most arduous one, and the above remarks have no other object than to show its interest and complexity.

We cannot yet hope for an immediate and complete solution of all the questions that have arisen in this rapid review of telephony; others still remain to be solved which have not been mentioned. But it seems that many of them might be examined to good purpose by men daily mixed up with practical difficulties who, by comparing their experience, especially if science was brought to bear on it, would certainly be able to throw a light on some points.

TRANSFORMERS.

Report of M. PICOU.

(Engineer and General Secretary to the Society of Electricians.)

1. *Principle.*—When an electric current is sent into an apparatus prepared to transform it into some other form of energy, the product E I of the difference of potential between the terminals and the intensity of the current measures the *power* which is absorbed at each instant by the apparatus in question.

If this is so arranged that it gives rise, itself in a circuit distinct from the first, to an electric current the product E′ I′ of the difference of potential at the terminals of this second circuit, and the intensity of the current will at each instant represent the electrical power furnished externally. We can assume that the electrical energy has simply undergone a transformation in the value of the factors the product of which represents its instantaneous value, whence the name of *transformers* given to the apparatus which realise it.

The first circuit receives the name of *primary*, the other is *secondary*.

The secondary power is always lower than the primary. The difference represents the energy absorbed by the different passive resistances set up by the working of the apparatus.

We designate as the *coefficient of transformation* the relation of the differences of potential at the terminals of the two circuits. It would be more accurate to define it as the ratio of the electromotive forces. There is, however, little difference between these two values. The name of transformers is reserved for apparatus which supply instantaneously in a secondary circuit the energy brought by a primary circuit.

Thus a secondary battery, or a group of condensers, the elements of which charged in tension can be discharged in quantity, will give a transformation of a group of values E I into another group; but the phenomenon is not instantaneous, and these apparatus are not included in the class of apparatus styled *transformers* or secondary generators.

2. The phenomena of induction form the basis of the working of the transformers. In a general manner the primary circuit produces a flow of force which passes through the secondary circuit. In order that the latter may be the seat of an electromotive force of induction, the flow of force that the primary circuit determines must be variable, and in order that the phenomenon may be reproduced indefinitely, a condition which is practically essential, the variation must be of a periodic nature.

There are several means of making the flow of force embraced by the secondary circuit vary. This result can be obtained, for example:

By the periodic variation of the primary current;

By the displacement of the circuits;

And also by their alteration.

The first method gives rise to transformers with alternating currents. These are fixed apparatus, in which nothing reveals to the eye the state of action or rest.

The second mode of variation of the flow embraced is realised by apparatus called *transforming motors* or *revolving transformers*.

Finally, the third mode has not as yet been applied to any industrial purposes, as there seem to be too great material difficulties of execution to be overcome.

3. *Transformers of the First Type.*—The earliest apparatus of this kind is the induction coil universally known by the name of its constructor, Ruhmkorff. Any description of it would be superfluous. We will merely remark that the interrupter and the condenser are accessories, not of the transformer, but of the source of the current.

The first idea of an industrial application of the induction coil seems due to M. Jablochkoff, who in 1878 made it an essential part of his kaolin system of lighting. These lamps, requiring a very high electromotive force, which would have rendered direct canalisation a very difficult matter, M. Jablochkoff proposed the process consisting of employing a primary current produced under a manageable electromotive force, and

transforming it by means of the induction coil into a secondary current of high tension, capable of feeding one or several lamps. An experimental installation of these apparatus figured in the Universal Exhibition of 1878.

About the same time a certain number of inventors proposed various methods of canalisation, in which induction coils constituted one of the essential points. It does not seem, however, that any of them obtained industrial results, for at the Electrical Exhibition of 1881 none of these systems were seen in application.

It was not until 1883 that Messrs. Gaulard and Gibbs, of London, brought transforming apparatus into use, and since then they have undergone important modifications and have been applied to industrial purposes.

It seems that up to this time inventors had in their minds this preconceived idea, that in order to profit by the advantages of a primary canalisation at high tension, the primary circuits of the transformers must be introduced *in series* into this circuit. The practical consequence of this fact was a great difficulty in the automatic regulation of the secondary sources constituted by the induced circuits in which were introduced the utilising apparatus. The grouping of these latter *in derivation* on the secondary circuit seeming to possess advantages which rendered it preferable to grouping them in series, it became necessary to have recourse to special apparatus for the regulating, whether automatic or by hand. In a word, these transformers were not self-regulating. Moreover, the properties of magnetic circuits not being as well known then as they are now, inventors employed magnetised masses of iron, presenting free poles, so that the flow of magnetic force had to effect a considerable passage through the air. The inconveniences of this fact were not then sufficiently recognised, and the presence of the free poles seemed a sort of manifestation of the play of the magnetic forces.

At the beginning of the year 1885 Messrs. Zipernowsky, Déri, and Blathy, of Buda-Pesth, and also Dr. Hopkinson, indicated the advantages of closed magnetic circuits, without poles, and described several forms of apparatus realising these conditions. These advantages were considerable, from the point of view of the rendering of the apparatus. All the lines of force remain in the interior of all the wires, or, in other words, the flow of force in each induced spiral is the maximum for each of them.

From this results evidently a better utilisation of the wire, leading to a minimum of internal resistance for a given electromotive force, a result which could only be obtained by a complete utilisation of the inducing flow of force.

Messrs. Zipernowsky, Déri, and Blathy also presented a complete self-regulating system of distribution, the principal point of which was the placing in derivation of the primary circuits of all the transformers on the principal circuit. The secondary circuits were connected in derivation together, or remained separate, according to local circumstances and the requirements of the distribution. This system was developed rapidly and adapted to several applications. Almost at the same time a large number of apparatus were created, infinitely variable as to arrangement, but all comprised in the category of transformers with closed magnetic circuit.

The Gaulard apparatus take this new form, and Messrs. Ferranti, Kapp and Kennedy, in England, and Westinghouse, in America, follow out the same idea in the construction of their transformers. The grouping in derivation has also obtained a firm footing, and is adopted in all the installations realised since that time.

At the same time, the progress made in the study of transformers is such that renderings of 90 to 95 per cent. can be obtained when fully charged. The very variable arrangements of transformers can all be classified under two principal types :—

In one the iron is inside the wires, and is completely enveloped by them. The Gaulard and Zipernowsky apparatus are of this kind.

In the other the wire is inside, and is enclosed in the pieces of iron. Messrs. Ferranti and Westinghouse use this type.

These two types are theoretically equivalent, and these transformers, of all forms, when well constructed, attain the same rendering.

The causes of loss are the same, viz., the resistances of the primary and secondary wire—the hystérésis of the iron—the Foucault currents, which may exist in consequence of the insufficiency of the division.

4. *Transformers of the second type.*—The revolving transformers, in which induction is due to the displacement of the circuits, are more particularly continuous current transformers.

In comparison with those already mentioned, they present the inconvenience of having movable organs, collectors, and brushes, which necessitate a certain amount of *surveillance*. But, on the other hand, they can give to the secondary current either the continuous or alternating form as required. The continuous current, as it presents a more extensive field of application, is generally preferred.

The *ensemble* of a receiving dynamo, working from another machine which becomes a generator, constitutes a group which may be considered as a transformer.

But this term is specially reserved for the more intimate union of two apparatus into one single one.

Several types have been proposed.

Every dynamo-electric machine possessing a double winding of wires on its armature, each of which is insulated from the other and connected with a special collector, constitutes a transformer. It is under this form that these apparatus have been brought into use in the applications that have been realised up to the present, in particular by Messrs. Paris and Scott in England.

These transformers are auto-motors, the motive force necessary to overcome the passive resistances is borrowed from the primary electrical energy. In the above arrangement it is always somewhat weak ; the loss on this head appears less in a transforming machine with a double-induced part than in two independent machines connected by a belt, for instance. Other types have been proposed which are not self-motive, and which only transform on the condition of receiving the movement of a independent motor.

The model proposed by Edison in 1883 is formed simply of a double armature, free to revolve in the centre of a mass of iron which completely envelopes it. Each armature may be considered as revolving in the resultant field produced by the current in each of them.

Finally, it has also been proposed to leave the armature immovable, and only make the brushes turn round their respective collectors. The effect of all these combinations is evidently the same. There are not in existence, to our knowledge, any important applications of these various apparatus. The ratio of the primary and secondary inductive electromotive forces is evidently constant in them. But their magnitude depends upon the speed imparted to the revolving organs.

5. *Calculation of the Elements of a Transformer.*—The calculation of a transformer consists in determining the number of spirals of the primary and secondary wires, the dimensions of the iron core round which they are wound, and the section of these wires. In all these apparatus the electromotive forces of induction are in proportion to the number of spirals of the primary and secondary wires. This ratio is generally called the *coefficient of transformation*. It is fixed in advance, according to the local conditions of the distribution. Let K be this coefficient.

It will then be sufficient to know how to calculate the primary wires, for example. The average induction, B, of the iron core, multiplied by its straight section Ω, gives the flow of force, f. Now, according to Maxwell's law, we get at each instant, and in each spiral :

$$e = \frac{d\,f}{d\,t}.$$

Let T be the duration of a complete period of the

alternating current, or of a half-revolution of the transformer, turning, say, at two inductive poles. We must know the law of variation of f with t, in order to deduce from it the value of e. In alternating currents, it is admitted that the curves which represent the current and the flow of force as a function of the time are sinusoids differently placed with regard to each other. We get then :

$$f = \text{F} \sin. m, t,$$

assuming that $$m = \frac{2\pi}{\text{T}},$$

and F being the maximum flow, whence

$$-\frac{d f}{d t} = e = -m \text{F} \cos m t$$

at each instant.

That which we have agreed to call the alternating electromotive force, E, being defined by

$$\text{E}^2 = \frac{1}{\text{T}} \int_0^{\text{T}} e^2 d t$$

may be calculated at once, and from it we shall deduce the primary electromotive force of a spiral of the transformer, provided that we fix the value of F, the maximum flow in the iron. We must be guided by the results of experiment in fixing this term at the value judged most suitable.

We see that, for a given transformer, the electromotive forces of induction are, all else being equal, in proportion to the number of periods in a given time. On the other hand, the Foucault currents and the work of hysteresis also increase with the number of periods, so that we are led on the one hand to increase these periods in order to increase the power of transformation of a given apparatus, and, on the other, to diminish them in order to increase the rendering.

The transverse dimensions of the wires of a transformer will be taken in relation with the intensity of the currents which pass through them, fixing a density of current which, on the one hand, does not lead to an excessive weight of copper, and, on the other, does not correspond to too great an energy absorbed in heating them, and which preserves, to the best possible degree, their qualities of self-regulation.

With revolving transformers, still speaking of the formula

$$e = -\frac{d f}{d t}$$

we remark that for the time T, the variation of the flow is 2 F, and we take, for the average electromotive force of a spiral

$$e = -\frac{2 \text{F}}{\text{T}}.$$

The calculation then resolves itself simply into that of dynamo-electric machines.

6. The industrial rendering is the ratio of the electrical energy expended in the secondary circuit outside the apparatus, to that which is supplied to the apparatus, measured at the primary terminals. With continuous currents there is no difficulty ; with alternating currents the only difficulties that arise are those which exist in the exact measurement of these currents. They belong to the department of electrometry, and we will not enter into them here.

The two systems of transformers present advantages and inconveniences proper to themselves. The alternating transformers have the advantage of having fixed organs, requiring no surveillance, which can be established anywhere, out of reach of the hand. They have a very high rendering, even when they work with a small charge, and are not susceptible of any accidental derangement when once established. The alternating machines which supply them can also be easily employed and superintended. But the alternating current does not lend itself readily to lighting ; it seems as yet difficult to use it for the transmission of mechanical work, and impossible to apply it to electro-chemistry.

The continuous current transformers are relatively more expensive. They require a more extensive installation and continual surveillance, and are subject to a more rapid rate of consumption ; their rendering is also not so high.

On the other hand, they can be adapted equally well to the distribution of lighting, mechanical work, and to electro-chemical applications, the principal of which is the charging of accumulators, which allow of a certain independence between production and utilisation.

The choice of either system therefore depends upon a careful study of the local conditions of the enterprise.

(To be continued.)

CONTINENTAL NOTES.

[FROM A CORRESPONDENT.]

FRESH experiments have lately been carried out at the Winter Palace, St. Petersburg, on the fatal influence of the electric light on the life of plants. It was observed that a single night's lighting was sufficient to cause the plants to become yellow and dessicated, which was followed by a fall of the leaves. The sudden passing of northern plants, used to sunless days and the weak light of the conservatory, into the dazzling light of drawing rooms must be regarded as the principal cause of this phenomenon. The rapidity and intensity of the pernicious influence of the electric light increase with the brightness of that light ; the plants which are not attacked directly by the luminous rays do not appear to suffer. The foregoing facts agree absolutely with those which were observed in the experimental conservatory at the exhibition of electricity in 1881. It is also remarked that the effects vary much with the nature of the electrical apparatus employed. If arc lamps be used, which give a light much charged with violet radiations, the injurious effects will be quickly observed ; if, on the contrary, incandescent lamps, which give a more yellow light, be employed, it is probable that the hurtful influence will be small, or not noticeable.

The Western Company of France is at the present moment experimenting with a system which is the idea of a watchmaker, M. Pouchard, which has as its object the automatic winding of clocks, watches, &c., at long distances by using the ordinary electric wires. The winding is procured by the aid of an electric motor inserted in the movements, which sets itself in motion when the clock has gone a determined time. Two elements of a Leclanché pile are sufficient to work this motor, which three or four times a day winds the spring. The setting of the automatic hour, by means of electricity, is also obtained in an equally simple and ingenious manner. A similar idea has, however, been employed in other countries.

Although, perhaps, rather late in the day, we may remark that the Belgian electrical show at the Paris Exhibition is a really fine one. In addition to lighting —in which they take an ample share in the galleries— there is an interesting exhibit from M. Van Rysselberghe, which includes a very simple Morse telegraphic apparatus furnished with anti-induction apparatus for telephony and telegraphy simultaneously by the same wire. The system adopted in Belgium is also in use in several other countries, notably in France since 1885. Near this apparatus is the show of the Belgian Company for Lighting and Long Distance Electrical Transmission, Limited, which lights a corner of the Machine Gallery. Some Liége firms have also some interesting apparatus for lighting by arc and incandescence. Among others there is an engine dynamo equal to supplying a light of 72,000 candles, the motive power necessary being 35-horse, and the speed 600 revolutions per minute. At another part of the Machine Gallery a large portion of the space reserved for Belgium is monopolised by electricity. Here is to be seen the magneto post, with Van Rysselberghe's microphone, by means of which it has been possible to correspond from

New York to Chicago, or a distance of 1,600 kilomètres. In the same section there are also lightning conductors designed for the protection of telegraphic installations, and also the electro-medical apparatus of Dr. Laroche designed for the Tournai madhouse.

We hear from Paris that further experiments of electrical generators have verified the results obtained by the Gassner dry piles, constructed at Liège by M. Peter Ehlis. The Gassner battery has given most regular results, both as regards electromotive force and internal resistance, which is low, not exceeding in all the measurements taken 0·6 ohm. In these trials its resistance, which was 0·4 the first day, only attained 0·42 ohm after eighteen days, and its electromotive force had only fallen 0·03 volt in the same time, while working continually through 400 ohms. We do not however, see anything very wonderful in this, for the external resistance is very high compared with that of the battery.

It is known, says a Belgian contemporary, that the Paris Telephonic Service has been taken over by the State. It is not so yet in Belgium. It appears that thie taking over cannot be carried out before two or thres years by the terms of the Act of Concession. But from observations made by the Government on the subject of the public telephone cabins, and M. Vandenpeereboom having stated his intention of assuming the direction of this service, the Bell Telephone Company, it would appear, is not indisposed to shift the burden on to the back of the State. Under these circumstances the State would perform, it seems to our contemporary, a singular operation. It would assume the most onerous part of the service, leaving the most fruitful to the company. However, as regards general interest, the taking over of the public cabins would be a first and notable improvement, because it is not doubtful that the State would more seriously organise this service, which has hitherto been established in a most rudimentary fashion.

The Special Electricity Commission appointed to adjudicate upon the electric lighting, &c., of Brussels, the members of which are MM. Buls, Burgomaster, Janssen (Public Works Department), Depaire, Martiny, Bède, and Pilloy, Communal Councillors, met for the first time last week to commence the examination of the tenders sent in by the different electricians in order to obtain the concession for the electric lighting of Brussels, and for the establishment of a general service for the distribution of electricity. These tenders are six in number, and are as follows :—The Belgian Thomson-Houston Electric Company, the Zurich Telephone Gesellschaft, the Liége International Electricity Company, the Brussels Company, L'Electrique, Messrs. Siemens and Halske, of Berlin, and, lastly, M. Van Rysselberghe. Most of the tenders provide for the establishment of a central station with continuous currents. One alone, that of the Thomson-Houston Company, sets forth a high tension system with transformers. The system, which is only theoretical as yet, fathered by M. Van Rysselberghe, provides for the establishment of a distribution of water at high pressure, similar to the hydraulic distribution of the Port of Antwerp. This distribution of water would have as its object the working of the motors which would produce the rotation of the electrical generators. As to Messrs. Siemens and Halske's system, which is in working on a large scale in several capitals, and which has just been applied to the lighting of Pesth, that also includes a central establishment with a fractionary distribution of electricity to all distances. Up till now, no decision has been arrived at. The Commission was to meet again to-day (Friday).

The Newcastle-upon-Tyne Electric Supply Company, Limited.—On Saturday last the Newcastle-upon-Tyne Electric Supply Company, Limited, tested two of their boilers and the first engine, a fine specimen of Robey's make, under steam, at their works in Pandon Dene, for several hours, with very satisfactory results. The dynamo electric machines, Mordey alternators, are expected to be in position during the next few days.

CORRESPONDENCE.

Electric Traction.

Noticing the mention of my name in your editorial notes of last week's ELECTRICAL REVIEW respecting a claim made by W. D. Sandwell, kindly allow me to state that the idea of employing a truck or trolley in connection with an electrical car was designed by me when W. D. Sandwell was in my employ from November, 1886, to the middle of October, 1887.

The plan I proposed was to use a suitably constructed truck or trolley to convey a set of charged cells to a car while it stood on the line, and to receive the discharged cells from the car, returning them to the charging depôt upon the trolley for recharging. The only difference between this plan and that of Sandwell's is, that mine was a means of feeding a self-contained car wih the cells, and Sandwell proposes to hook the same thing to a car like a tender to a locomotive. It was during the time that Sandwell was in my employ that he saw and obtained a knowledge of the construction of an electromotor for the first time, and particularly the utility and advantages to be gained by the employment of the double armature motor I had previously patented for tramcar propulsion, and for other purposes. It would be impossible for Sandwell to construct a motor on the lines proposed by him without infringing the patent taken out by me in February, 1886, especially in the face of the disclaimer now printed in his specification. The disclaimer above referred to, which Sandwell was compelled to insert in his specification, substantially, in my opinion, upsets, all the claims that follow it, no matter whether the magnet moves or not. It may assist your readers to form a fairly clear opinion upon the subject, and the validity of patent No. 2,783 of 1886, if I here quote from the decision of the Comptroller of Patents, H. Reader Lack, Esq., given on the 23rd of February last, when an endeavour was made to upset this patent on the ground that it had been anticipated by others.

The following is the extract :—

"I am of opinion that Jarman's invention of an electro-motor, with two armatures on one shaft, employed in such a manner that one armature is cooling while the other is in use, has not been foreshadowed in either Jensen's or Danchell's specifications, for in neither of these is there any indication that the two parts of the double electro-motor are to be used alternately. Hence, so far as the evidence that has been placed before me goes, I am bound to consider Jarman's invention as new in principle."

Following this is the disclaimer which the Attorney-General (Sir R. Webster) compelled Sandwell to insert in his specification, which is as follows :—

"I wish it to be understood that I do not claim placing two armatures on the same axle, one only of such armatures being operative at the same time."

It becomes evident from the foregoing that if Sandwell uses two armatures on the same axle, one of them must be inoperative while the other is operative ; hence he would be using that which he does not claim.

The value of a patent with such a disclaimer inserted in the specification, as well as a description of gearing in the final specification which is neither mentioned nor hinted at in the provisional, may be well left for your readers and yourselves to decide.

Suffice it to say that Patent No. 2,783 of 1886 is the property of the Electric Tramcar Syndicate, Limited, together with others that have been granted to me for improvements connected with electrical propulsion and traction. As several tramcars will before long be in practical operation, embodying the improvements these patents cover, the owners will not fail to protect and safeguard the rights granted by these patents from infringement.

A. J. Jarman.

September 16th, 1889.